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COMING MEETINGS

January 15, 1952—New York Section Midwinter Luncheon at Park Sheraton Hotel, New York. Secretary: R. K. Blanchard, 50 W. 50 St., New York 20, N.Y.

February 13—New Jersey Section Winter Meeting at Essex House, Newark. Secretary: C. B. Tygert, Box 178, Newark 1, N.J.

13–15—Indiana Section at Lincoln Hotel, Indianapolis. Secretary: George G. Fassnacht, 366 Good Ave., Indianapolis 19, Ind.

A.W.W.A. 1952 ANNUAL CONFERENCE
Kansas City, Mo.
May 4–9

Reservation forms have been mailed to all members, and all reservations will be cleared through the A.W.W.A. office. The hotels have agreed to accept no reservations for the 1952 Conference except as they are requested on the standard form prepared by the A.W.W.A.

Accommodations at Fourteen Hotels

All Technical Sessions and Exhibits at Municipal Auditorium

March 24–26—Southeastern Section at Bon Air Hotel, Augusta, Ga. Secretary: T. A. Kolb, 89 Alexander St., Charleston, S.C.

26–28—Illinois Section at LaSalle Hotel, Chicago. Secretary: J. Leslie Hart, Western Sales Manager, U.S. Pipe & Foundry Co., 122 S. Michigan Ave., Chicago 3, Ill.

April 3–5—Arizona Section at Maricopa Inn, Mesa. Secretary: Harry S. Jordan, San. Engr., Bureau of Sanitation, State Dept. of Health, Phoenix, Ariz.

11–12—Montana Section at Northern Hotel, Billings. Secretary: Arthur W. Clarkson, Assistant Director, Div. of Sanitary Engineering, State Board of Health, Helena, Mont.

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Contents

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Journal

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Application of Molecular Filter Membranes to the Bacteriological Analysis of Water

By Alexander Goetz and Noel Tsuneishi

A paper presented on October 25, 1951, at the California Section Meeting, San Francisco, by Alexander Goetz, Assoc. Prof. of Physics & Project Director, and Noel Tsuneishi, Research Bacteriologist, both of the California Institute of Technology, Pasadena, Calif. The paper is based on work done for the Biological Dept., Chemical Corps, Camp Detrick, Frederick, Md., under Contract No. W-18-064-CM-207 with the California Inst. of Technology.

FOR several decades, German and Russian scientists have attempted to perfect a technique for using cellulose nitrate and cellulose acetate membranes for bacterial analyses. During World War II, German bacteriologists were forced to turn to this method when many of their laboratories were destroyed by bombing. The success of the Germans led to a thorough postwar research program at the California Institute of Technology in the conduct of which the methods of producing molecular filter membranes were investigated and considerably perfected. A number of standardized types of such membranes, one of which is especially designed to fulfill the requirements of standard methods of water bacteriology, were then developed.

This article describes the nature of molecular filters * and techniques for their use in water bacteriology. It shows that the molecular filter is capable of retaining all bacteria during filtration and of lending itself to improved methods of culturing and incubation. Numerous variations in procedures are described.

* The authors use the term "molecular filter" because of certain structural characteristics which distinguish the filter material developed at the California Inst. of Technology and described in this article from a variety of filter membranes used in the past. This molecular filter material is identical with the "membrane filters" used by Clark, Geldreich, Jeter and Kabler as described in their *Public Health Reports* article (reference 6). Eventually the discrepancy of nomenclature will be adjusted, but it is necessary for all concerned to understand that both terms refer to the same filter material.

Fig. 1. Photomicrograph of Dense Filter Paper Surface (Whatman)

Fig. 2. Photomicrograph of Molecular Filter Surface

Both photos taken with reflected darkfield illumination, the filter being dyed with methylene blue. Magnification approximately 100 ×

The advantages of molecular filter techniques over the present standard method of bacterial analysis are so numerous and so distinct that this method may give entirely new aspects to the field of water bacteriology.

Introduction

The molecular filter in its present form dates back more than sixty years to the work of Sanarelli (1) with collodion membranes that were impervious to bacteria but permeable to their toxins. To H. Bechhold (2), however, is attributed the first systematic study of the physico-chemical nature of a large variety of such membranes. After 1911, many authors in different countries contributed studies of the properties of porous collodion membranes. Their production methods were greatly improved by Zsigmondy and his collaborators—chiefly Bachmann, 1916–18—which has since led to an industrial production of such filters on a small scale at the Membran-Filtergesellschaft, Sartorius Werke, in Goettingen, Germany.

In the 1930's, new interest arose from the contributions of W. J. Elford in England and P. Grabar in France. Both investigators developed and taught the technique of producing collodion membranes with controlled pore sizes to such an extent that numerous laboratories were able to produce them for their own purposes; but it appears that, except in Germany and Russia, no effort toward industrial production of such membranes on any scale was made. More detailed bibliographies on the subject of the physical properties of the membranes in their earlier stages of development by Bechhold, Zsigmondy, Elford and Grabar and numerous other authors are available in three monographs (2–4).

Shortly after World War II, the senior author visited Germany under the auspices of the Joint Intelligence Objective Agency of the Armed Services and had the opportunity to study recent German development in the field of membrane filtration. The results of his investigation are contained in Fiat Final Report 1312 (5). The potentialities of these methods for the detection of biological warfare agents interested the Biological Department of the Chemical Corps of the U.S. Army and led to research contracts with the California Institute of Technology. It was during the three years of research effort under this contract that the investigations and results described here were accomplished.

In view of the widespread significance of the molecular filter techniques in the field of civilian defense, the U.S. Public Health Service was kept apprised of the work at the California Institute of Technology and has carried on similar research at the Environmental Health Center in Cincinnati with materials prepared by the California group. Certain aspects of this work, particularly those on the selective detection of water-borne pathogens, have been published in activity reports of the Environmental Health Center, in an issue of *Public Health Reports* (6) and, more dramatically, in *Life* magazine (August 13, 1951).

Nature of Molecular Filters

In the present method of sanitary water analysis, the number of bacteria in a sample of water is determined either by means of the plate count, gas production, or indicator reaction in test tubes. With the plate count, the quantity of water examined is generally limited to 1–2 ml.; with test tubes, to

10–100 ml. By means of the molecular filter technique described here, however, much larger quantities of water can be examined, for, with samples containing relatively few bacteria per liter, the entire number can be concentrated on the surface of the molecular filter. Another unique advantage of the filter is derived from the fact that the bacteria contained on its surface are separated from their previous environment—that is, separated from any enzymes or other

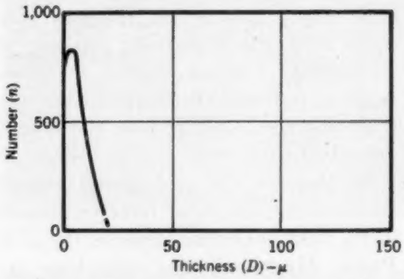


Fig. 3. Depth Distribution of Particles Retained on Molecular Filter

Number of 0.2- to 0.5-μ particles retained (n) *from hydrosol are plotted against total thickness* (D) *of the molecular filter. It will be noted that all visible particles are retained within the first 15μ of the molecular filter.*

inhibiting substances that may be in the liquid medium in which the bacteria have been suspended. This fact is particularly advantageous if bacteriophages are present.

Basically speaking, the application of the molecular filter to bacteriology is founded on the combination of two simple facts which have been known, as such, for a considerable time:

1. That certain polymeric substances, such as cellulose and some of its esters, can form uniform, coherent, but porous, films (such as collodion, cellophane, etc.), which permit diffusion of aqueous liquids

2. That microorganisms, when deposited on one surface of a very thin porous film, can utilize a nutrient which diffuses through the pores if it is brought into wetting contact with the opposite side of the film.

The combination of these possibilities for bacteriological assay and detection hinges on the availability of a filter material that combines rapid flow characteristics with complete retention of bacteria on a surface with uniform size and frequency of pores so that *each* deposited cell can be reached by the nutrient and thus, if viable, develop into a visible colony. The molecular filter in its present status approaches these requirements sufficiently well to warrant closer discussion of its nature.

Because of the extremely small size of the structural elements of the molecular filter, its texture is smooth and beyond the resolving power of a microscope. The difference between a very tight filter paper and the surface of a molecular filter, both of which have approximately the same rate flow, is illustrated in Fig. 1 and 2. The resulting performance of the filters differs accordingly.

The interstices in the cellulose "felt" of the filter paper produce a variation over a wide range in effective pore size, and the retaining action of particles in the felt is largely due to the length and tortuosity of each individual channel. This means that filtration through such a fibrous filter is based on a "depth action" rather than the "screen action" of molecular filter membranes.

During the three years of research at the California Institute of Technology, the molecular filter has been substantially improved and refined to a high degree of uniformity. Extended

experimental studies on the European product indicated that the uniformity of the pore structure was not always sufficient to permit reproducibility to the degree required for methods capable of standardization in water bacteriology. Another disadvantage in practice was the necessity to boil the membranes in water for an extended time and then to protect them against drying prior to use. During the three years of research at the institute there were developed new production methods that improved flow rates and uniformity and rendered it unnecessary to treat the filter material prior to use.

The production methods involved are beyond the scope of this paper, but it is expected that material of the type described will soon be produced on an industrial scale. The molecular filter material can be made with various sizes and spacing of pores. The type of material designed for bacterial water analysis has a flow rate of 1,000–1,200 ml. per minute through an area of approximately 10 sq.cm. at a vacuum of 23–30 in. mercury (aspirator). The pore volume is 75–80 per cent of the volume of the leaf. The latter is about 150μ (6 mil) thick and has, according to theoretical calculations, about 500 million pore openings in the area used for filtration.

The membranes used for this type of application are circular disks 50 mm.

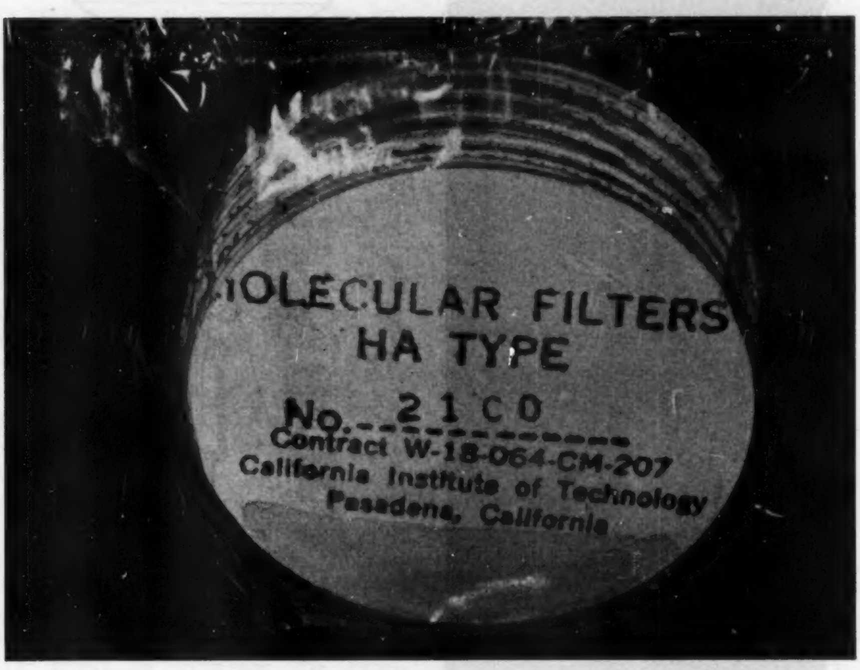


Fig. 4. Standard Package of Molecular Filters

Ten molecular filters with nutrient pads in sterile condition are sealed in cellophane to make the package.

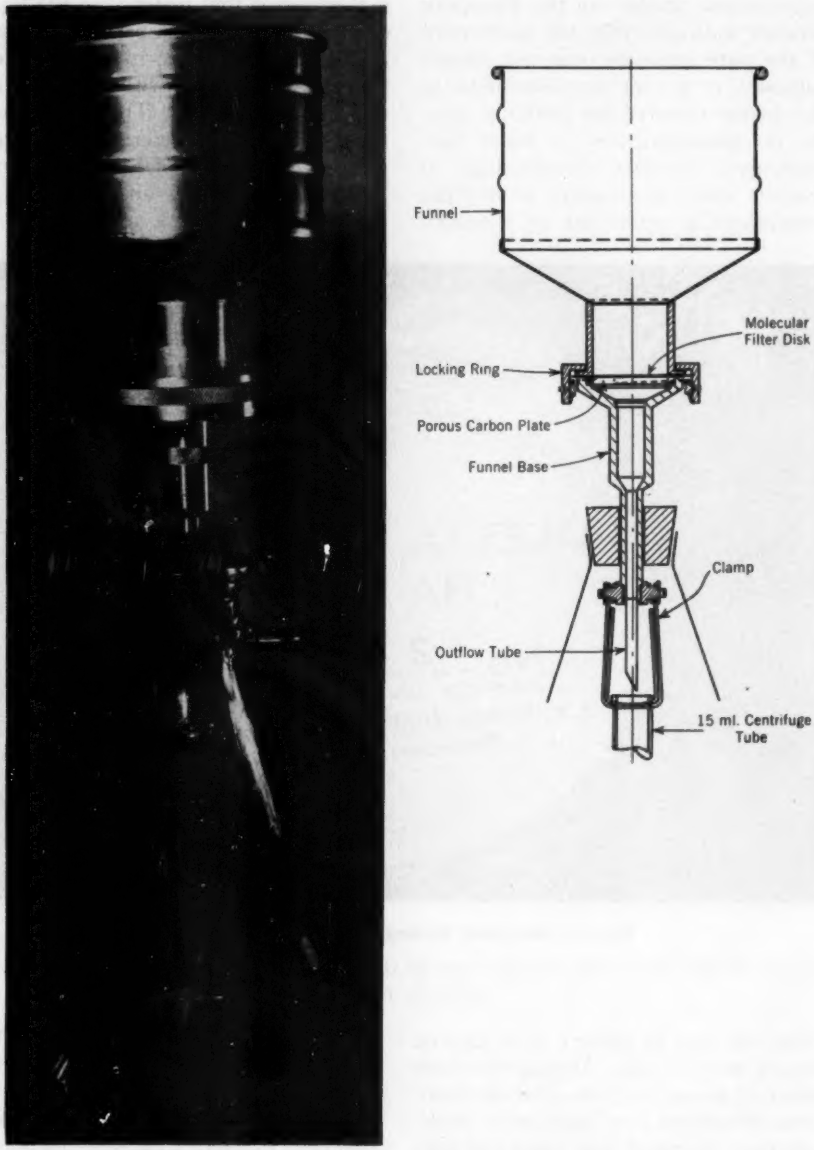


Fig. 5. View and Diagram of Hydrosol (HS) Filter Unit

Operations of the various parts shown are described in the text.

(2 in.) in diameter. Their chemical constitution is a mixture of cellulose esters which form a submicroscopic sponge-like structure of very uniform interstitial dimensions, which dimensions can be controlled over a very wide range in the manufacturing proc- .removing a fraction of the filter, important property is that the pore size is very small on one side of the leaf and much wider on the other side (anisomorphous pore structure), making possible the "screen action" obtained. The flow should always be entering the leaf at the side of the narrow pore openings.

As a result of the uniformity and peculiar pore structure, particle retention is restricted to the surface of the molecular filter and is quantitatively complete—if the proper pore size for the particular particle class size is chosen.

The "depth" distribution of inert pigment particles of 0.3 to 0.6 μ size (7) has been determined on a molecular filter of the type used for water bacteriology by filtering a hydrosol, removing a fraction of the filter, imbedding it in a microscope slide and counting the particles over a known area through an oil-immersion objective for several depth layers—changing layers by changing the focus. When the count of the particles in the same area is plotted against the focal position of the objective, a depth distribution is obtained (Fig. 3). This distribution indicates that countable particles were discovered only in the first 10 μ of the total filter thickness of 150 μ, in spite of sufficient transparency of the whole sample.

So far, the only molecular filters produced in the United States were prepared at the laboratories of the California Institute of Technology. They are packaged in a cellophane bag containing 10 filter disks, each disk being separated from the next by a pad of inert blotting material (see Fig. 4). The filters are sterilized by means of ethylene oxide, to which cellophane is permeable, so that the material contained in the bags can be sterilized after closure and requires no further treatment prior to use. Within the near future, it is expected that molecular filters will be available on an industrial scale in sufficient quantity to permit their widespread adoption by water works and public health laboratories throughout the country.

Techniques and Operations

In order to facilitate filtration of liquids through molecular filters, several special filter holders have been developed. They have been designed to avoid undue stresses in the filter leaf even at pressure differentials exceeding one atmosphere.

Figure 5 shows the filter holder (HS unit) especially developed for bacteriological tests of water supplies. The unit consists of a funnel of stainless steel—capacity about 1 liter—which can be clamped on a base inserted in a filter flask. The standard size (50 mm.) molecular filter disk is supported by a circular plate of porous carbon. (coke), which is mounted into a rim of stainless steel, held in the base. Porous carbon, because of its high uniform porosity, its rigidity and its chemical neutrality, is preferable to fritted metal or glass. The porous area of the plate defines the area of filtration (and deposits) on the filter disk and is equivalent to 9.6 sq.cm. (1.49 sq.in.).

The total area of the standard molecular filter disk is about 19.6 sq.cm. (3 sq.in.); 10 sq.cm. of which constitutes the peripheral rim of the filter.

This rim area is sandwiched between metal flanges and is not used for filtration.

The lower part of the funnel forms the upper of the two flanges between which the filter disk is clamped. The small rubber-rimmed casters which roll on a double helix below the lower flange when turned. In this manner, a resilient pressure between both flanges on the molecular filter is effected without a gasket, and aseptic bacteria-tight seal of the molecular filter between the two flanges is effected by a locking ring which can rotate freely around the lower part of the funnel. The inside of the ring has two insertion and removal of the filter leaf by the use of a forceps is made quite simple.

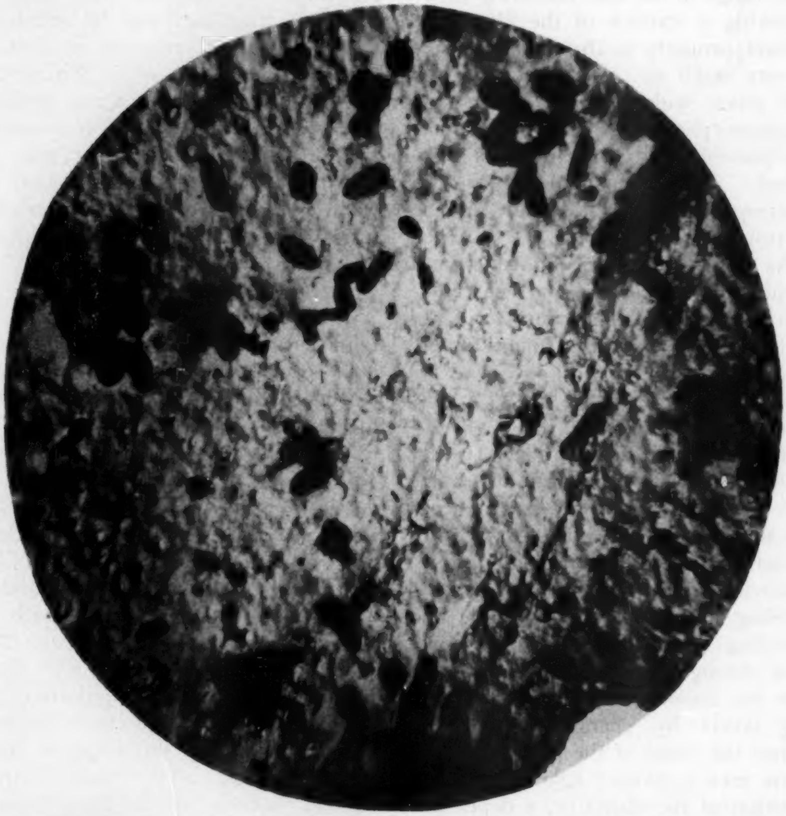


Fig. 6. Electron Photomicrograph of Molecular Filter Surface With Deposit of *Esch. coli* (3,750 X)

The deposit (about 130 cells) indicates a density of about 500 million organisms per sq.cm. of molecular filter surface. Note absence of resolved pore structure, and surface deposits of the cells.

The lower part of the filter unit carries a clamp at the outflow tube which

can serve as a holder for exchangeable sterile glass tubes (15 to 50 ml.) if collection of the filtrate is required. In this manner the necessity for a sterile filter flask for each filtration is avoided.

The filter operation itself is quite simple: The sterile filter unit is inserted with a rubber stopper into a 1-liter filter flask connected with a vacuum line or pump through a three-way cock. The molecular filter leaf is placed on the unit with flat-bladed forceps, and the filter funnel is clamped into place with medium pressure. Care must be taken to ascertain that flanges are clean and that the filter fits well into the recess on the base. Depending upon the quantity of liquid to be filtered (up to 1 liter) the filtration is generally completed in less than 1 minute, 100 ml. of clear water passing in 5 to 10 seconds. After the last liquid has passed through the filter, the funnel is removed and atmospheric pressure is reestablished in the flask by means of the three-way cock. The filter is then taken from the base, with forceps, and is placed on the nutrient pad.

The filter funnel and the supporting base must be sterilized after each use. Such sterilization can be effected most rapidly and conveniently by means of an alcohol flame. Each of the two parts can be readily inverted over a swab of cotton that has been saturated with alcohol and ignited. The forceps can be sterilized in a similar manner or merely over a Bunsen flame.

One of the most valuable properties of the molecular filter is the fact that it permits the growth of cells upon the upper surface by diffusion of liquid nutrient through the pores from the lower surface. This diffusion is effected when the bottom surface of the filter disk is placed on the surface of a liquid or semiliquid in such a manner that a uniform wetting contact is established. Obviously uniform growth development of the microorganisms on the molecular filter depends on two main conditions:

1. The retention of the microorganisms *upon* the filter surface and not *within* the pore structures

2. The uniform wetting contact of each deposited cell by the nutrient diffusing upward through the filter.

Condition 1 is met by the previously mentioned particle retention within a few microns of the surface (Fig. 3), and this characteristic is illustrated by an electron photomicrograph (Fig. 6) of a surface that had retained a dense suspension of *Esch. coli*. The surface deposit of all individual cells is obviously due to the extremely fine pore structure. Such retention of cells is important because of the lack of traceability of colonies developing in the interior structure of the molecular filter. The molecular filter material fulfills this condition despite an effective pore size large enough to permit a flow rate as high as one liter per minute.

Condition 2 is important for the uniform development of every cell deposited on the surface. The degree to which this condition is fulfilled can be estimated by the uniformity of colony size of a bacterial deposit consisting of only one type of organism. Figure 7 demonstrates this for a few colonies of deposited *Esch. coli* organisms after incubation of 16 hours (37°C.) and Fig. 8 for a heavy deposit after incubation for 12 hours (37°C.). Despite the extremely dense growth in the latter, the colony sizes are mostly the same, and only those which have been too closely juxtaposed appear larger because of confluent growth. On the other hand, if a mixture of

different organisms with different growth rates is retained, the colony sizes are different but closely identical for each species, as shown in Fig. 9 for a mixture of *Staph. aureus* (100 small colonies) and *Esch. coli* (170 large colonies) after incubation for 12 hours.

The exact mechanism by which the nutrient reaches the organisms deposited on the molecular filter so that it can be utilized by them is far from simple and not quite understood in all detail even after several thousand experiments. The withdrawal of nutrient from the pad into the filter by capillary action, as such, is apparently not sufficient, for it is quite possible to obtain no growth or only regional growth in spite of uniform deposits on the surface and apparently uniform diffusion of the nutrient in adequately prepared molecular filters.

Obviously the chemical nature of the screen surface and its hydrophilic character are of critical importance. The

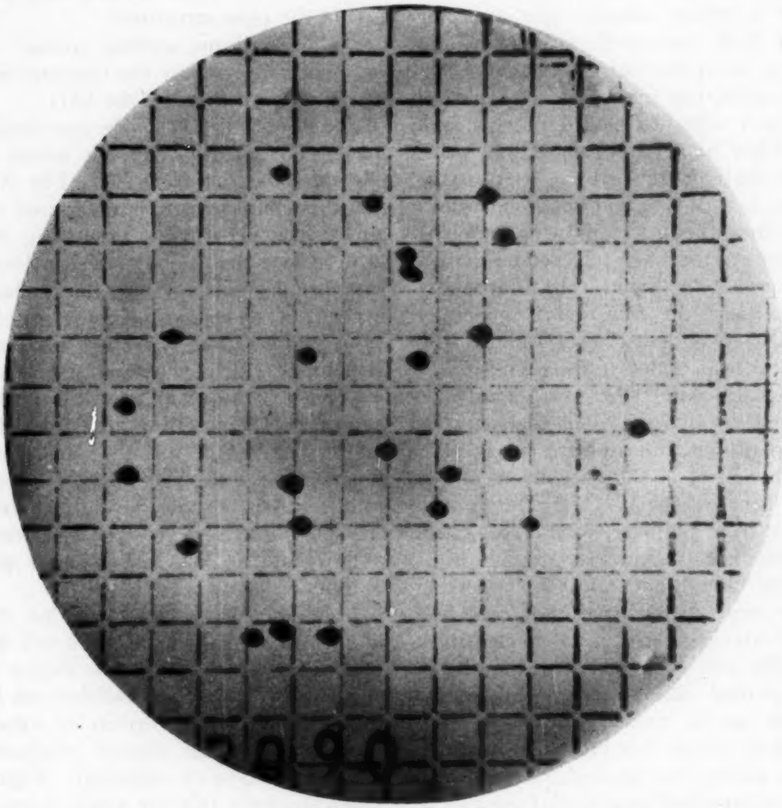


Fig. 7. *Esch. coli* Culture on Molecular Filter From Hydrosol

After 16 hours at 37°C. incubation. Colony size is 0.6–0.8 mm.

methods developed in the preparation of the molecular filter have overcome this difficulty.

The incubation of the molecular filter upon the nutrient pad is best accomplished in a humid atmosphere over a saturated towel when placed in the incubator. This requirement is quite critical, as drying out has been found to be one of the most common causes of failures of adequate growth development.

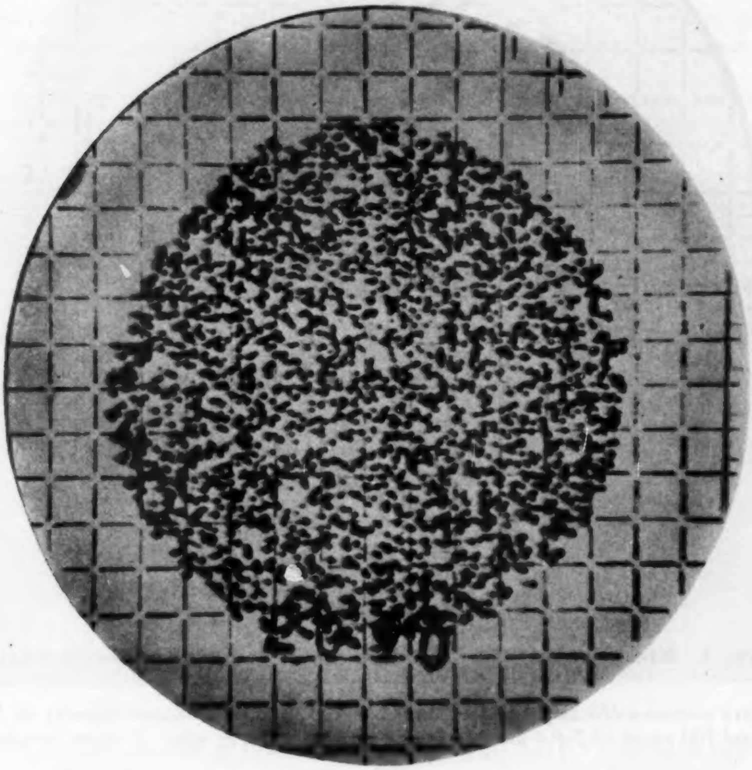


Fig. 8. *Esch. coli* Culture on Molecular Filter From Hydrosol

After 12 hours at 37°C. incubation. Colony size is 0.3–0.5 mm. Molecular filter carries about 2,400 colonies. Adjacent colonies begin to coalesce.

at the correct temperature for the organism being tested. The optimum conditions for growth occur when the atmosphere above the molecular filter disk is highly humid. As no water drop must come in contact with its upper surface, however, the molecular filter upon its nutrient pad is inverted

The foregoing considerations indicate that the bacteriological uses of molecular filter material, when compared with standard techniques, require substantial deviations, almost all of which appear to be simpler and more economical. As it is apparent that only a minute quantity of nutrient

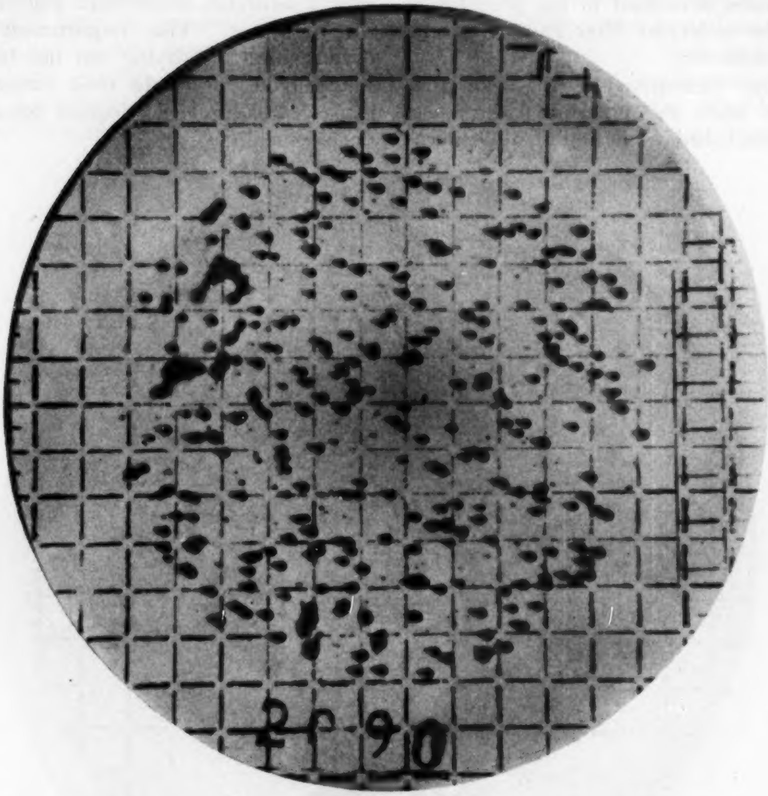


Fig. 9. Mixture of *Esch. coli* and *Staph. aureus* Cultures on Molecular Filter From Hydrosol

Mixture contains 270 large (0.4–0.6-mm.) already partly confluent colonies of Esch. coli *and 100 small (0.2–0.4-mm.) colonies of* Staph. aureus *after 12 hours incubation.*

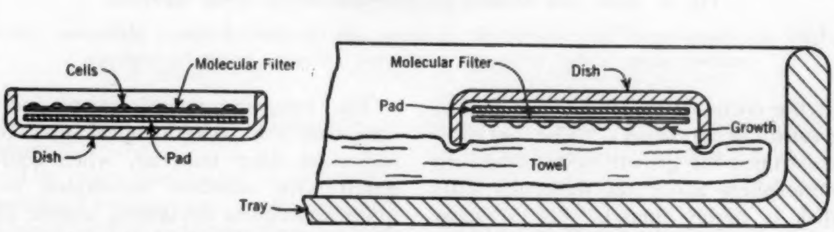


Fig. 10. Schematic Views of Molecular Filter, Nutrient Pad and Dish

View A *is prior to incubation; View* B, *during incubation*

is required for filling the interior pore volume of the filter, the following method has been developed:

As a "container" for the nutrient, a circular disk of heavy blotting paper of the same size as the filter leaf is used. This paper is carefully extracted to avoid the presence of growth-inhibitory agents and is known as the "nutrient pad." The liquid capacity of the dry pad is 2 ml.; thus each square centimeter of the molecular filter has available approximately 0.1 ml. of nutrient, sufficient for supporting extreme growth density.

The sterile dry pad is placed into the bottom of a previously sterilized dish (the lid of a small standard Petri dish, 60 × 15 mm.) and the nutrient is then pipetted into the dish. It will be absorbed completely by the pad and no free liquid should remain. As an alternative, the nutrient can be pipetted into the dish prior to the insertion of the pad (Fig. 10). The lids of larger Petri dishes are then used for covering these pads temporarily to prevent contamination. The Petri dish, with pad and filter adhering to its bottom by surface tension, is then put in an inverted position into the incubation tray (Fig. 11).

These incubation trays consist of pyrex baking trays (available commercially for household use, size $8\frac{1}{2} \times 13$ in.). The bottom of each tray is coveral uniformly by a suitably folded towel wetted with about 200 ml. of water (prior sterilization not required). These pyrex trays can be stacked on top of each other and should be put into the incubator prior to the test in order to avoid delay in incubation time caused by the considerable heat capac-

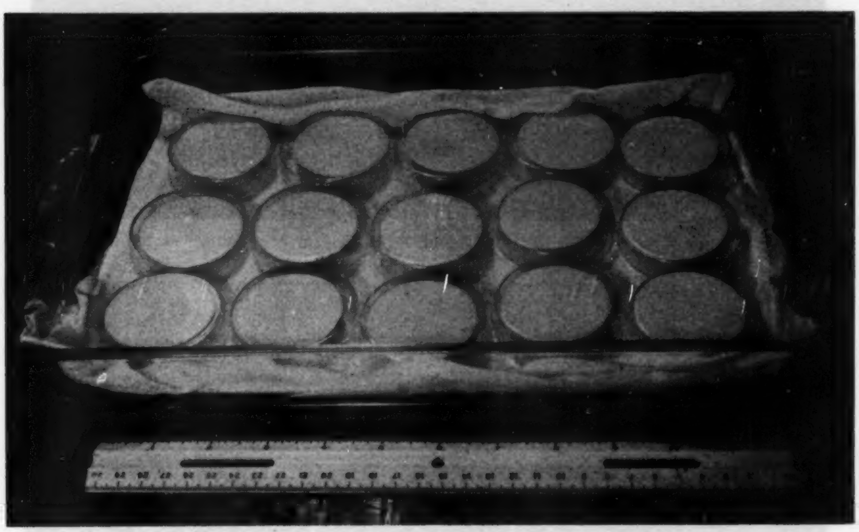


Fig. 11. View of Molecular Filters During Incubation

View shows arrangement of dishes in tray on hydrating towel. Foot ruler will give idea of size.

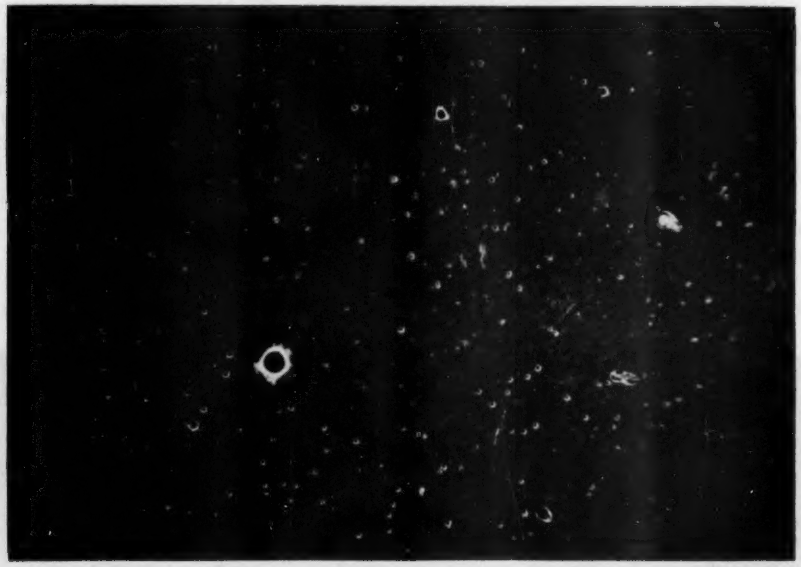


Fig. 12. ***Esch. coli*** **Colonies After Four Hours' Incubation at 37°C.**

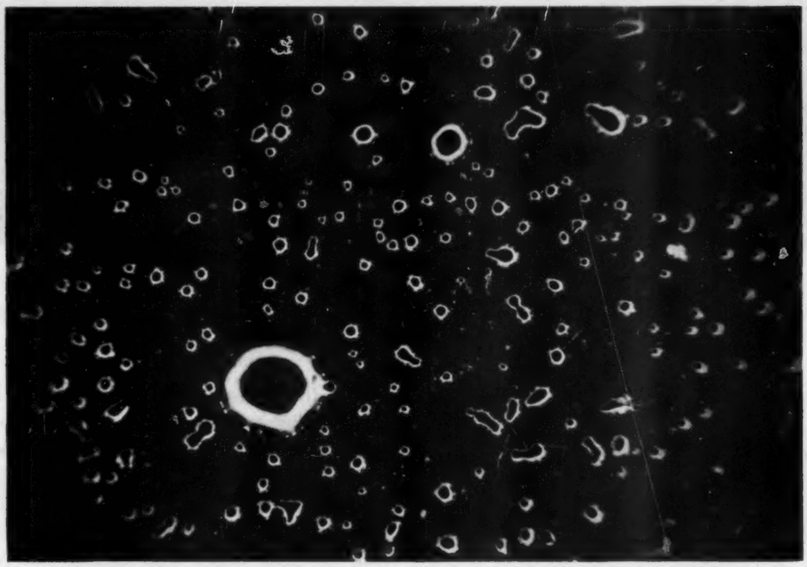


Fig. 13. ***Esch. coli*** **Colonies After Six Hours' Incubation at 37°C.**

Photomicrographs of 4,900 organisms per sq.cm. on black molecular filter. Magnification is 31 ×.

ity of the dishes and the water. Each pyrex dish can conveniently accommodate fifteen small Petri dishes (Fig. 11).

One of the primary advantages of the molecular filter procedure results from the fact that visible colonies often develop in as little as four hours of incubation. These colonies are readily visible to the naked eye, but their several squares can be counted with the aid of optical magnification, and the number on the entire filter can be calculated accordingly. A further aid in the counting and identification of colonies is afforded by intense low-angle illumination from an artificial light source coupled with the use of a low-power stereomicroscope. The combination of the side lighting and the

Fig. 14. *Esch. coli* Colonies After Seven Hours' Incubation at 37°C.

Photomicrograph of 4,900 organisms per sq.cm. on black molecular filter. Magnification is 31 ×.

counting has been facilitated by several procedures developed at the California Institute of Technology laboratory. In the manufacturing process, a standard square grid pattern is imprinted on the top surface of the filter disk, such that each square represents $\frac{1}{100}$ of the area used for filtration. Thus when colonies are tiny and numerous, those in low-power magnification accentuates the minute colonies and greatly assists in their identification at an early stage.

The visual contrast can be increased even more by the use of molecular filter material that has been dyed with black or other suitable dyes. Methods for dyeing have been developed in such a manner that the dye is fixed to the

filter structure itself and does not leach into the nutrient. Furthermore, no inhibitory action is imposed by the dye.

One of the advantages of the molecular filter technique over that of plate culture is the larger margin of countability, by a factor of 30 to 50 times. With the standard agar technique, the maximum number of colonies that can be cultured and identified without overlapping is 8 colonies per sq.cm. or about 500 over the whole area of a standard size dish. With the molecular filter, on the other hand, colonies can be identified with a density as great as 500 per sq.cm., or about 5,000 for the whole area.

It was noted above that colonies can be counted after an incubation period as short as 4 hours. Such short incubation periods are not only possible, but desirable in order to prevent the merging of adjacent colonies. The effect of this merging is shown dramati-

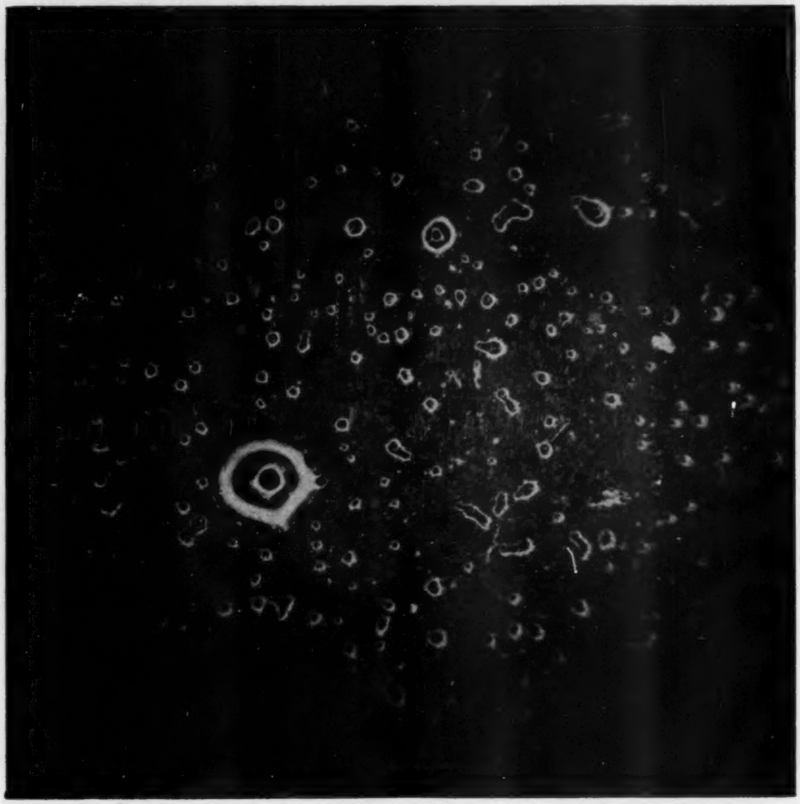


Fig. 15. Composite Photomicrograph of *Esch. coli* Colonies

Composite of colonies shown in Fig. 12–13, showing confluence of adjacent colonies during fourth and fifth hours of incubation.

cally in Fig. 12–16. These photographs of the same cultures after 4, 6, and 7 hours show how the total count will decline with time, owing to the merging or overlapping of colonies.

When an adequate colony size is reached, the incubation can be interrupted and the filter removed from its nutrient pad and dried on a blotter. The molecular filter disk can then be preserved for permanent record and future reference by pasting it on paper and protecting its surface with transparent foil (such as cellophane) (Fig. 17). It is also possible to stain the filter disk for purposes of differentiation, although certain precautions are necessary, as the filter material itself absorbs many of the customary stains.

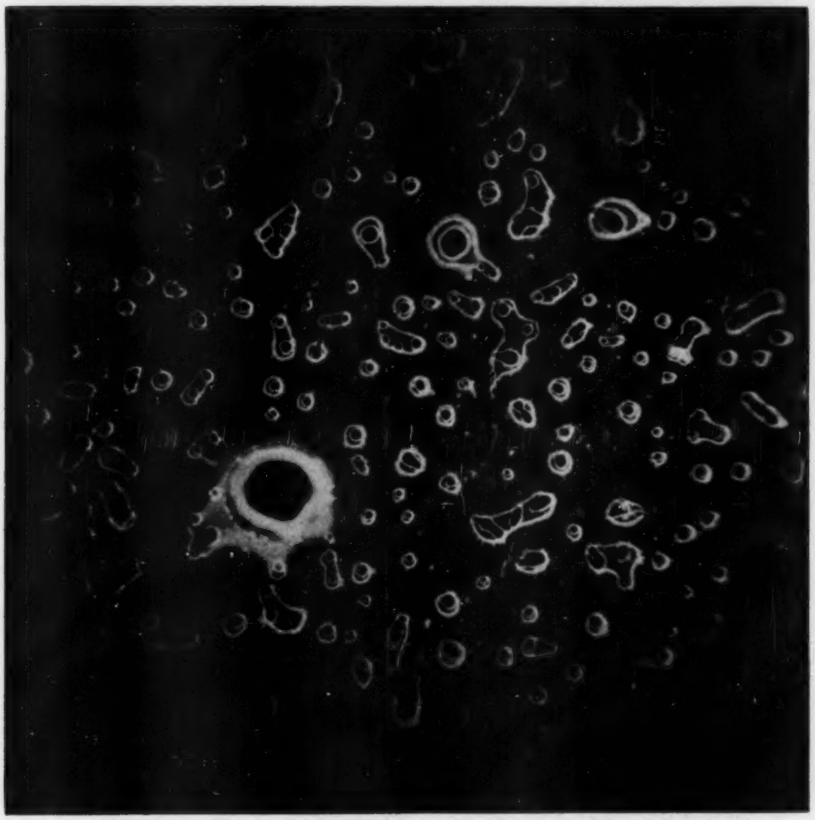


Fig. 16. Composite Photomicrograph of *Esch. coli* Colonies

Composite of colonies shown in Fig. 13–14, showing confluence of adjacent colonies during sixth and seventh hours of incubation.

Records of this type have been kept unchanged for several years at the California Institute of Technology laboratory. If court cases or other legal proceedings are apt to occur, such per-

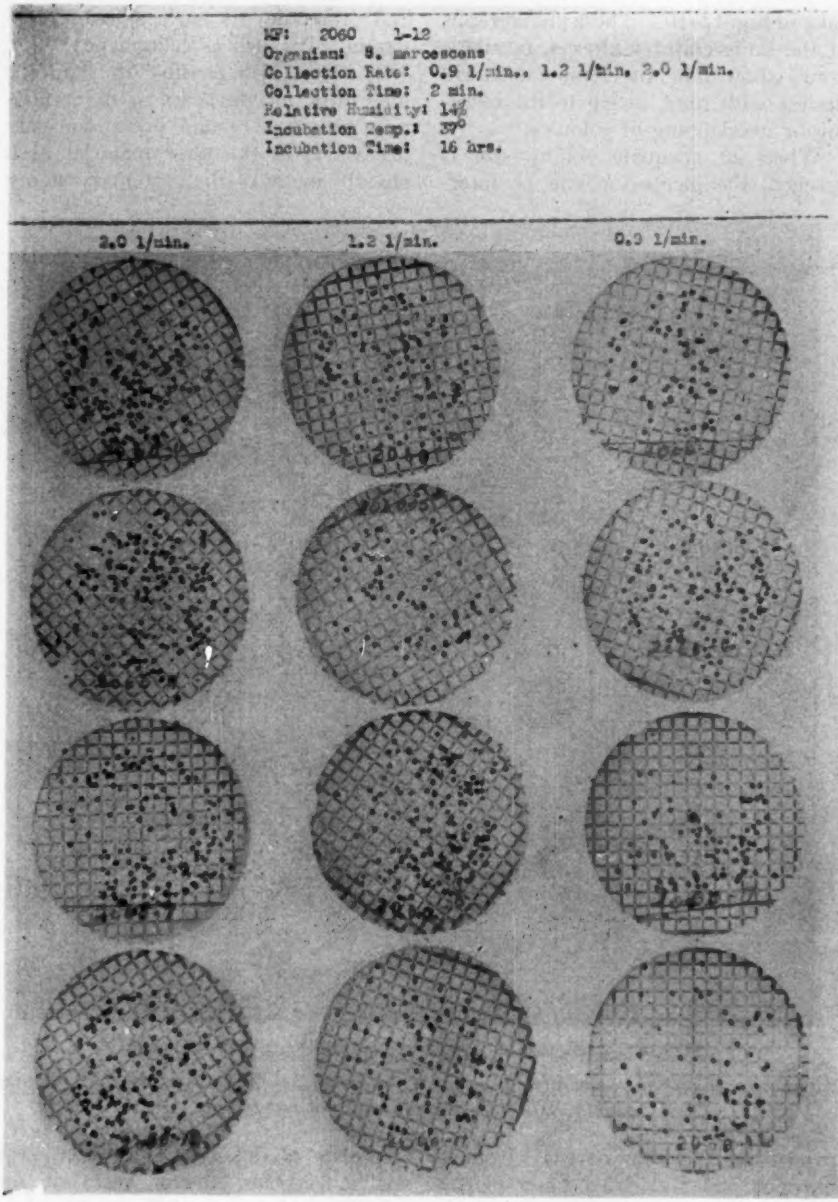


Fig. 17. Preserved Molecular Filter Samples

A typical page from a record book into which the actual filter disks have been pasted.

manent records become exceedingly valuable.

Bacteriological Efficiency

In determining the efficiency of the molecular filter, three questions come immediately to mind:

1. Are all bacteria removed by the filter; and, if not, what number or percentage is apt to pass through the filter?

2. How does the number of colonies on the molecular filter, incubated as described above, compare with the number of colonies that develop on the standard agar plate count?

3. How does the number of coliform organisms compare with the most probable number as determined in the presumptive test?

These questions have been answered to the satisfaction of current investigators as indicated below.

The effectiveness of the molecular filter in retaining all bacteria from a water solution is best demonstrated by filtering about 50–100 ml. of a diluted broth culture containing a total of from a thousand to a million organisms. The filtrate is collected in the sterile tube and then passed through a second molecular filter sheet contained in a second filter unit or tested by another standard method.

TABLE 1

Effectiveness of Molecular Filters in Retaining Various Bacteria

Test Organism	Number of Tests	Number of Organisms Retained	Number in Filtrate	Test of Filtrate
Staph. aureus	1	$8\text{–}9\times10^5$	0	Second passage through second molecular filter
	1	4×10^5	0	
	1	2×10^5	3	
	1	$6\text{–}9\times10^5$	0	
	1	$7\text{–}8\times10^5$	1	
	1	$7\text{–}9\times10^5$	0	
Esch. coli	1	10^5	0	Lactose broth and agar plate
	1	4×10^2	0	
	2	8×10^3	0	
	2	6.6×10^4	0	
	2	3.4×10^4	0	
	1	6.5×10^4	2	
	3	6.5×10^4	0	
	1	2×10^4	2	
	2	2×10^4	0	
Staph. aureus *B. subtilis (globigii)*	1	$\begin{cases} 2\times10^5 \\ 3.5\times10^5 \end{cases}$	0	Serial passage through second molecular filter
	1	$\begin{cases} 6\times10^5 \\ 3\times10^5 \end{cases}$	0	
	1	$\begin{cases} 7.5\times10^5 \\ 1\times10^5 \end{cases}$	2	
	1	$\begin{cases} 7.5\times10^5 \\ 1\times10^5 \end{cases}$	0	

The results of such a procedure, as shown in Table 1, indicate that in the

majority of tests the retention was complete; the occasional occurrence of a few colonies may be caused by leakage around the edge of the filter or to accidental contamination. Such leakage can be proved by adding to the filtrate, prior to filtration, a very small portion of a noninhibitory dye. Inas-

TABLE 2

Comparative Plate and Molecular Filter (MF) *Counts*

Test Organism	Number of Agar Plates	Avg. Agar Plate Count	Dilution Factor	Plate Count, *per ml.*	Number of MF	Volume Filtered, *ml.*	Avg. MF Count	MF Count, *per ml.*	Ratio of Counts *MF: Plate*
B. subtilis (*globigii*)					4	10	2	0.2	1.33
					4	20	3	0.15	1.0
	4	150	1,000	0.15	4	40	7	0.18	1.2
					4	80	12	0.15	1.0
					4	160	24	0.15	1.0
					4	10	19	1.9	0.83
					4	20	44	2.2	1.0
	4	220	100	2.2	4	40	90	2.2	1.0
					4	80	177	2.5	1.13
					4	160	377	2.3	1.04
	3	265	3	86	5	25	2,040	82	0.95
TOTAL TESTS	11				45	Average			1.02
Esch. coli					4	10	9	0.9	1.09
					4	20	12	0.6	0.77
	4	83	100	0.83	4	40	40	1.0	1.20
					4	80	63	0.8	1.05
					4	160	134	0.8	1.05
	3	25	50	0.5	3	50	21	0.4	0.80
	3	270	50	5.5	3	50	273	5.5	1.0
	4	23	1	23	10	50	1,040	21	0.91
TOTAL TESTS	14				36	Average			0.963
Sergatia marcescens	4	105	1	105	9	10	1,076	107.6	1.02
	4	35	1	35	7	10	380	38	1.08
	4	18	1	18	10	50	882	17.5	0.97
TOTAL TESTS	12				26	Average			1.02
Staph. aureus	3	74	3	25	10	50	1,370	27	1.08
	4	47	5	9.4	10	50	417	8.3	0.88
	3	75	10	7.5	10	50	383	7.7	1.02
	4	240	5	48	14	50	2,560	51	1.06
	3	36	3	12	10	50	686	13.7	1.13
	3	111	4	28	11	50	1,260	25	0.89
TOTAL TESTS	20				65	Average			0.990

much as this dye is removed in part by the filter, its coloring indicates the path of the liquid. If there has been an adequate seal at the flanges of the filter unit, the colored circle on the filter will extend to the rim where the leak has been. Such leaks can be caused either by the presence of dirt on the flanges, by bent or chipped equipment, or by excessive compression of the filter between the flanges, resulting from excessive tightening of the lock-rings.

The most significant factor in the evaluation of the molecular filter technique, as such, and the suitability of a particular molecular filter for water assays is obviously the agreement between counts taken from standard techniques and those obtained from parallel tests on molecular filter material.

Table 2 presents a compilation of data based upon counts taken from aqueous bacterial suspensions of four different types simultaneously plated on agar and filtered through molecular filters. Each horizontal line represents a series of 3 or 4 plates tested in parallel with 4 to 14 molecular filtrations. Each plate was made to represent 1 ml. at various dilutions in order to avoid an uncountable number. The filters were passed by varying quantities (10 to 160 ml.) of undiluted suspension in order to test the reliability of the count for a wide range of colony density (2–2,560) on the filter surface. The last column of the table shows the ratio between the average molecular filter and plate counts and indicates the mean deviation of counts for each type of organism. The average deviation of a few per cent evidently lies well within the normal error in spite of the fact that the maximum growth density on the molecular filter material was 1,000 times the minimum, whereas on the plates this factor was less than 10.

Nutrients

As might be expected from the peculiar conditions of colony development on a molecular filter surface, the nutrient compositions and concentrations for best growth development vary from standard formulations used in agars and liquids. Generally speaking, concentrations of the nutrient two to four times higher than customary are used —in quantities (2 ml.), however, that are very much smaller.

An excellent formula for the rapid determination of total counts from water with the use of a redox indicator has been the following (used in Fig. 7, 8 and 12–16):

Sol A

Peptone "M" (Albimi) *	40 g.
Yeast autolysate (Albimi) ...	6 g.
Dipotassium phosphate (K_2HPO_4)	3 g.
Sodium chloride (NaCl)	5 g.
Distilled water	1,000 ml.

Adjust to pH 7.0 with 10 per cent KH_2PO_4 solution.

Sol B

Dextrose	500 g.
Distilled water	1,000 ml.

Sol C

TPTZ †	1 g.
Distilled water	100 ml.

Prior to use the solutions are mixed in the following ratios (by volume): 100 A + 1B + 4C.

For the determination of coliform organisms, the molecular filter technique is particularly useful because it supplies a direct count instead of a statistical approximation (M.P.N.) even for very low concentrations. Among the numerous possibilities of applying

* A product of Albimi Labs., Inc., Brooklyn 2, N.Y.

† A product of Synthetical Labs., Chicago, Ill.

known differentiating media with the suitable modifications (such as Endo), reference may be made to the application of the long-known Gassner medium (8), which, if used in the molecular filter technique, gives a clear and rapid indication of coliform suspects in low concentrations. The formula contains solely lactose as sugar and no, or only a very small concentration of, buffer. It contains two dyes: a pH indicator, Ink Blue BJTBNA–80 * (blue in acid) and a yellow dye, Fast Mordant Yellow GD * which partially inhibits cocci and spore formers but does not affect the development of *Salmonella* and coliform organisms. The acidity, produced by the fermentation of lactose, stains the colonies and their immediate environment on the filter blue, while the other colonies appear green-yellow. Lactose fermenters are recognizable after about ten hours. A nutrient suitable for molecular filter application is the following:

Sol A

Peptone "M"	40 g.
Yeast autolysate	6 g.
Sodium chloride	5 g.
Distilled water	1,000 ml.

Adjust to pH 7.5 with sodium hydroxide; autoclave.

Sol B

Yellow indicator	2 g.
Distilled water	100 ml.

Dissolve the dye in the water and filter through normal filter paper. Boil for 2 minutes.

Sol C

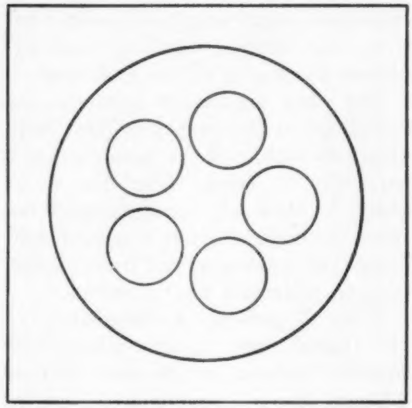
Blue indicator	1 g.
Distilled water	100 ml.
Lactose	50 g.

Dissolve the dye in the water and filter through normal filter paper. Add the lactose and boil for a few minutes.

* A product of General Dyestuff Corp., New York, N.Y.

The mixture of the final nutrient to be applied in 2-ml. quantities to the pads is composed as follows (by volume): (10 B + 10 C) + 100A.

Sols B and C are shaken thoroughly before adding to A. The final mixture should have a green appearance. Each component should be sterilized alone, as the mixture will not stand autoclaving.



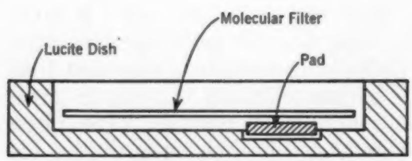


Fig. 18. Schematic View of Lucite Dish for Nutrient Pads

Dish carries five small nutrient pads for the study of the effect of variations in nutrient composition on the growth on the molecular filter surface.

In order to produce the proper color conditions on the surface of the molecular filter, it has been found useful to dye the filter in the yellow dye prior to use in order to avoid an excessive absorption of the blue dye.

Addition of 10–40 parts of TPTZ solution (1 per cent in distilled water)

to the above mixture has sometimes proved useful for discriminating rapid from slow lactose fermenters because the growing colony of rapid fermenters will produce sufficient acidity to remain distinctly blue before the redox indicator turns red, whereas the slow lactose fermenters will turn red faster and not develop the blue color appreciably. This method of combining the redox indicator with a pH indicator in order to discriminate between *rates* of growth and acidity may indicate a mode of approach for rapid detection of the *Esch. coli* suspects without the necessity for confirmation. It appears, however, that more work must be done to evaluate this possibility definitely.

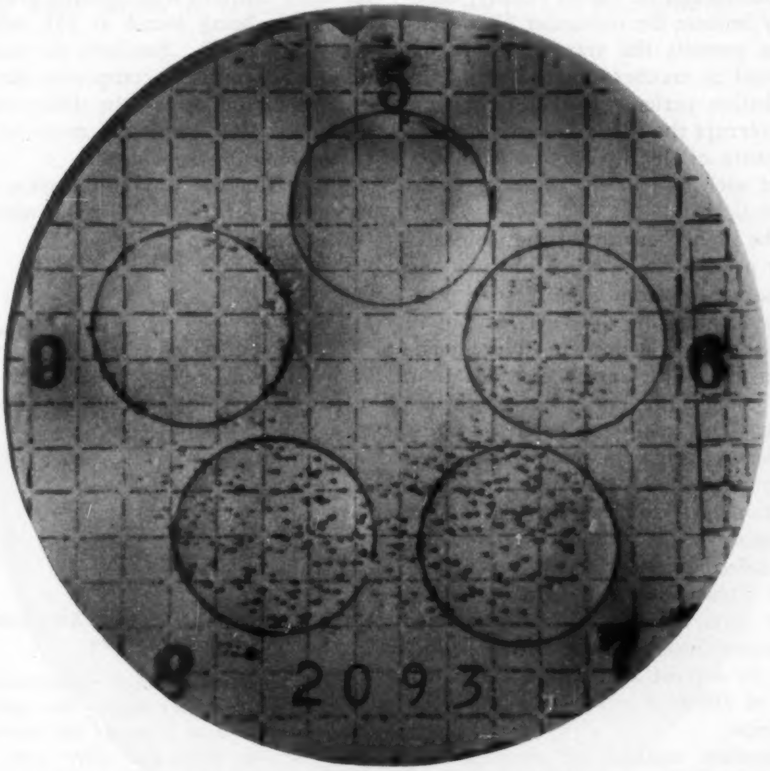


Fig. 19. ***Staph. aureus*** **After Incubation for 16 Hours on Nutrient at Five pH Values on a Single Molecular Filter**

Growths at pH, 5, 6, 7, 8 and 9 are shown. A uniform deposit of about 1,000 cells was first laid down on the filter and subsequently the molecular filter was brought in contact with and incubated in the lucite dish. The inked circles indicate roughly the position of the nutrient pads under the filter.

Possible Variations in Procedure

The nature of the molecular filter allows it to be used for a great number

of variations in procedure and technique. The most obvious of these variations derives from the fact that the nutrient concentration and substances for the purpose of differentiation of organisms can be varied readily, especially because the molecular filter technique permits the transfer from one nutrient to another at any time of the incubation period. It is also possible to interrupt the growth at any stage by exposure of the filter to an inhibitory agent such as ethylene oxide or ultraviolet light.

The unique quality of the molecular filter in minimizing cross-diffusion and spreading of colonies permits the technique of exposing different sections of the same filter deposit to different nutrient media varying in concentration, pH, composition, or other characteristics. This quality of molecular filters renders possible the simple and rapid determination of the optimum composition of a nutrient for a particular organism. A simple way to economize on molecular filters and to avoid multiple filtration is to cut the molecular filter upon which organisms have been deposited into two, four or more sectors and to deposit each upon a nutrient pad of different concentration or composition.

Another method of accomplishing the same effect is to employ a lucite incubating plate into which five circular recesses have been cut (Fig. 18), placing into each of the recesses a small pad of blotting paper suitable for the reception of the separate nutrient solutions. The molecular filter leaf with the retained deposit may then be imposed upon the pad and the whole assembly inverted and incubated on a towel as described above. In this manner it is possible rapidly to obtain information on the growth-promoting or growth-inhibiting effects of different formulations. Figure 19 shows a typical example of the effect of variation of pH between 5 and 9 on the growth or development of *Staph. aureus* for the same nutrient with optimal growth conditions being found at pH values between 7 and 8. Similarly the variation of each nutrient component can be evaluated rapidly, and the differentiating value of nutrients for mixtures of bacteria can be determined.

This reduction in cross-diffusion can be utilized in another method aiming at early differentiation of the total bacterial flora. It consists of the use of a "selector disk." The "selector disk" is a molecular filter, of the same dimension as that used for filtration, that has been impregnated (or imprinted) partially with one or more selectively inhibitory agents and subsequently dried. This selector disk is placed upon the pad after the latter has been impregnated with nutrient, and the mo-

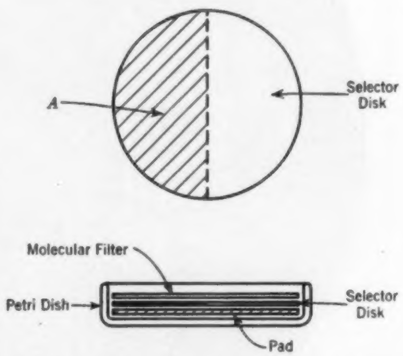


Fig. 20. Schematic View of Arrangement of Selector Disk

Half of the selector disk is imprinted with a selective inhibitory agent; the selector disk is interposed between the nutrient pad and the molecular filter used for filtration.

lecular filter carrying the microorganisms is put above the selector disk (Fig. 20). The nutrient, which diffuses from the pad, has, thus, to pass the selector disk before it reaches the filter which carries the organisms. If while the lack of cross-diffusion in both filter disks prevents the spreading of the addition agent. Consequently, the deposited cells will develop only in those sectors in which the nutrient does not prevent their growth.

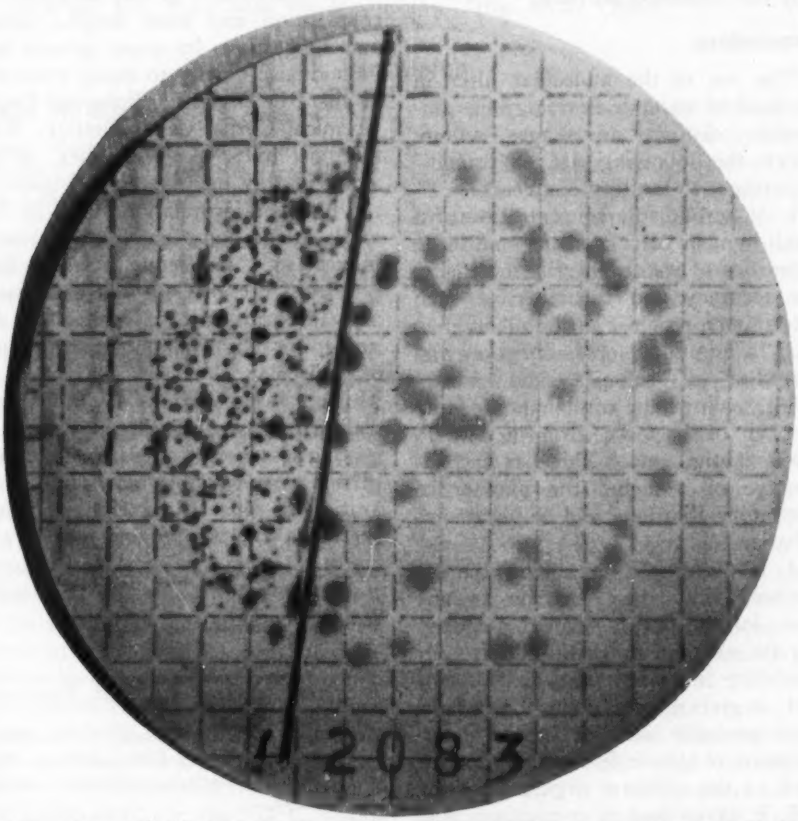


Fig. 21. Separation of Gram-Negative Organisms From Mixed Growth on Selector Disk

A hydrosol containing a mixture of Staph. aureus *and* S. marcescens *grown on an interposed selector filter, the larger part of which was impregnated with lauryl sulfate. The smaller part gives total count; the larger, Gram-negative organisms only.*

it passes through a region of the selector which is impregnated with a water-soluble agent, the nutrient will dissolve the latter and reach the organisms in an accordingly modified form,

Figure 21 pictures the result with a mixed culture, with one-half the selector disk impregnated with lauryl sulfate. The impregnated region shows selective growth of Gram-negative or-

ganisms, whereas the other permitted the development of the total flora. The advantage of this method is seen particularly in large-scale assays, for which standard preprinted selector disks could be supplied, thus permitting the use of only one standard nutrient.

Conclusions

The use of the molecular filter in the field of water bacteriology has numerous distinct advantages among which the following are of primary importance to sanitary engineers:

1. It permits the concentration of a small number of organisms from large quantities of water, thereby increasing the accuracy and reliability of such determinations.
2. It minimizes cross-diffusion and spreading of colonies, and, consequently, allows the combination of any number of bacteria, from a few to 5,000 at one time. This has the advantage of reducing the number of laboratory dilutions and duplicate incubations.
3. It permits separation of the organisms from their nutrient at any time, for the purpose of either changing the nutrient or partially or totally inhibiting further development.
4. It gives a direct count instead of a most probable number in the determination of lactose-fermenting bacteria, such as the coliform organisms.
5. It saves time in comparison with present standard procedures.
6. It requires much less laboratory space and practically no glassware.
7. It permits better and faster differentiation of bacteria.
8. It gives a permanent record in the form of the preserved filter disks.

The molecular filter technique, as improved and developed at the California Institute of Technology laboratories during recent years, promises to render the practices utilized by sanitary engineers in water analysis more efficient and economical.

Acknowledgments

The authors are greatly indebted for cooperation and most helpful advice and suggestions by many groups and individuals: chiefly to many members of the PD Division, Biological Dept., Chemical Corps, Camp Detrick, Md.; foremost to R. A. McKinney, whose work in this field developed some of the nutrient formulations used in this work, in addition to many helpful techniques; to J. J. Weigle, Prof. of Biophysics, Univ. of Geneva, Switzerland, and California Inst. of Technology, for numerous electron photomicrographs of molecular filter surfaces; to J. E. McKee, Assoc. Prof. of San. Eng., California Inst. of Technology, for suggesting Gassner's original medium and giving most valuable aid in the preparation of this manuscript; and furthermore to the following members of the staff of the project: H. Bucherer, R. E. Densmore, Mrs. S. S. Goetz, R. A. Goodding, A. F. Holser.

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Discussion

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An urgent need exists for less time-consuming methods in bacteriologic water examination. It appears that the molecular filter will allow such examination to be completed in a considerably shorter time than that now recommended by *Standard Methods* (1).

At the Environmental Health Center in Cincinnati, molecular filters and filter-holding apparatus prepared in Dr. Goetz' laboratory have been used (2). Aside from experiments designed for the acquisition of basic technique and experience, however, little of the authors' work has been repeated. Work at Cincinnati has comprised intensive investigation of bacterial count, quantitative estimation of the coliform group, and the culture of *Salmonella typhosa* from water. Analogous tests for the first two are described in *Standard Methods* (1) in the "37°C. standard agar plate count" and the "confirmed test" for the coliform group, respectively.

Bacterial Counts

In routine procedures recommended for the standard agar plate count for the estimation of bacterial density in water (2), 1 ml. or less of the sample is plated in a Petri dish. If there are less than 30 or more than 300 colonies on the plate, the count is not considered statistically accurate and is discarded. Because the bacterial densities of treated waters commonly are less than 30 organisms per ml., the standard plate count loses much of its value. The molecular filter, on the other hand, will retain all the bacteria contained in any quantity of water that can be forced through it, and is, therefore, applicable to the examination of water of almost any bacterial density.

It is recognized that not all living bacteria in a sample of water can be cultivated on a single medium. Thus, several media have been evaluated for use with the molecular filter by comparison of counts of the same samples by standard plate count technique. In tests at Cincinnati it has been shown that double strength Albimi "M" medium with 0.5 per cent lactose, adjusted to pH 7.0 with potassium hydroxide, gives the most consistent results. This is a modification of the basic medium described by Dr. Goetz. Colonies are counted after 18 hours' incubation at 35°C. in a saturated atmosphere, using a wide-field microscope and a magnification of approximately 15 diameters.

Bacterial counts made on several waters of varying bacterial densities by the use of the Albimi "M" medium with the molecular filter have been compared with counts obtained on the

same waters by standard methods. Waters of low bacterial densities require samples up to 500 ml., whereas those with large bacterial populations are diluted with sterile water to secure a fraction of a milliliter for examination. The ideal sample will produce between 50 and 300 colonies on the filter. Samples of low bacterial density (less than 30 colonies per ml.) cannot be compared on the basis of a standard agar plate count, so, for these samples, the M.P.N. must be used to estimate total bacterial density.

It has been shown that the molecular filter method has marked advantages over the standard plate method for the enumeration of bacteria in samples of low bacterial density, such as finished waters from the distribution system, because samples of any size up to a liter may be examined. The method is readily applicable to the counting of bacteria in any relatively clear water with high or low bacterial density and in turbid waters of high bacterial content. The method shows savings in elapsed time for test, equipment, materials, labor and space.

Coliform Group Count

The coliform group or some of its members have been used as the indicator of water quality throughout the entire civilized world. In the United States, the coliform group is in general use as a pollution indicator, without distinction between fecal and nonfecal strains. Because the procedures of *Standard Methods* are considered to be the nearest approach to the ideal test, the "confirmed test" was the standard of comparison in the evaluation of the molecular filter.

The major problem in the application of the molecular filter to the enumeration of organisms such as those of the coliform group is the development of selective media. Preliminary investigations of several established differential media have been made with water samples containing a member of the coliform group and some non-lactose-fermenting organisms. The following modification of Endo medium, used as a broth, has been found most satisfactory:

ENDO BROTH—EHC (Environmental Health Center) MODIFICATION

Basal Medium

Lactose	20 g.
Neopeptone (Difco)	20 g.
K_2HPO_4	7 g.
Distilled water	1,000 ml.

The constituents are dissolved in the water, using moderate heat if necessary. Medium is adjusted to pH 7.5, using KOH solution. It is tubed in 30-ml. portions and sterilized in the autoclave for 15 minutes at 121°C.

Sodium Sulfite Solution

Nine per cent aqueous solution of anhydrous Na_2SO_3 is freshly prepared in sterile distilled water.

Basic Fuchsin Solution

Basic fuchsin	3.0 g.
Ethyl alcohol	50 ml.

The dye is dissolved in the alcohol and sufficient distilled water is added to make 100 ml. The dye solution is stored in the refrigerator to reduce evaporation of the solvent.

Use of the Medium

To one 30-ml. tube of the basal medium is added 1.0 ml. of the sodium sulfite solution and 1.0 ml. of the basic fuchsin solution. It is thoroughly mixed by agitation of the tube, and applied to the blotting pads in 2–2.2 ml. quantity. This medium is used the same day.

Basic fuchsin, the indicator used in Endo's medium, may differ in dye content from lot to lot. It is, therefore, necessary to standardize the propor-

tions of basic fuchsin to sodium sulfite with each new lot of dye. The fuchsin-sulfite ratio is critical in the finished medium.

Studies have been continued with the Endo's medium, using pure culture suspensions of coliform organisms. It has been demonstrated that a significant increase in growth is obtained when the organisms are incubated for 2 hours of preliminary enrichment on lactose Albimi "M" medium before being transferred to the Endo medium. Selective media, such an Endo's, have a slightly toxic action to bacteria, which may suppress growth unless the organisms are in an actively growing phase. It has been shown that the growth on a filter incubated 2 hours on Albimi "M" medium followed by 14 hours on modified Endo medium is at least equivalent to coliform growth on nutrient agar plating medium.

Experiments to determine the elapsed time required for the finished test for coliform organisms have shown that 90 per cent of the bacteria present have grown after a 10-hour incubation period but, of this number, only 20 per cent have developed the typical differential characteristics of a coliform colony. The results indicate that the minimum elapsed time for a reasonably complete coliform count (93 per cent) must be at least 16 hours. The shorter incubation period of 10 hours could be used as a rapid qualitative test. There remains a possibility of developing new or improved media which may shorten the incubation period.

The technique recommended by the Environmental Health Center for the coliform test is simple. The sample is filtered through the molecular filter and cultivated for 2 hours on Albimi "M" medium. Following the enrichment period on nondifferential medium, the filter is transferred to a Petri dish containing an absorbent pad saturated with Endo medium. Incubation is continued for approximately 14 hours. The colonies are counted with the source of light above the filter. All dark colonies with a metallic sheen are counted as coliform colonies. The pink or colorless colonies are non-coliform organisms.

Excessive colony density on the molecular filter should be avoided. If the total number of colonies exceeds approximately 600 on the filter or the number of coliform colonies is in excess of 350, the quantitative recovery rate drops rapidly. Coliform organisms in excessive numbers tend to grow together on the filter and are difficult to identify accurately. This fact probably accounts for the reduction in quantitative count.

The classical description of coliform colonies on Endo agar does not apply to growth on the molecular filter using modified Endo broth. All the *Esch. coli* and most of the *Aer. aerogenes* and intermediates develop a metallic sheen over the surface of the colony. A few of the *Aer. aerogenes* and intermediates may be missed, but the increased accuracy of the filter procedure compensates for this small loss.

The molecular filter method with the EHC Endo medium gives coliform densities comparable with those obtained by the *Standard Methods* M.P.N. procedure, although the M.P.N. values fluctuate over a wider range than do the corresponding values obtained by the filter method. It appears that a coliform determination by the molecular filter method has a greater degree of reliability than the M.P.N. coliform determination, and the M.P.N. procedure may require 96 hours to finish the "confirmed test," whereas the filter

technique requires 16 hours. In the confirmed test, two to four different observations have to be made, and transfers of from five to fourteen positive lactose tubes to brilliant green lactose bile broth may be necessary. In the filter method, after an initial 2-hour period on enrichment medium, the filters are transferred to Endo medium and counted 14 hours later.

Culture of *S. typhosa*

The isolation of pathogenic organisms from water supplies is not a routine method in the determination of water quality. In epidemiological investigations such a procedure might be of special value when the dangerous organisms are not associated with the coliform group or other normal indicators of pollution. Direct cultivation of *S. typhosa* from water is difficult even when one or more of the excellent special media are used, because of the very small number of the organisms in the limited quantity of sample that can be examined. Several investigators have attempted to overcome this difficulty by concentrating the bacteria from a large sample by use of the molecular filter. Mueller (3) successfully used this procedure in her investigation of an epidemic of typhoid fever in Hamburg.

In work at the Environmental Health Center, a number of modifications of differential media have been examined in order to determine their growth-promoting ability, quantitative recovery rates and differential characteristics of typhoid colonies. The medium found most satisfactory is a double-strength bismuth-sulfite broth. Using this medium, the typhoid colonies appear, after 30 hours incubation, as smooth glistening colonies 2 to 3 mm. in diameter with jet black centers surrounded by a thin clear white border. The colonies are characteristically surrounded by a black or brownish zone which may be several times the size of the colony and which, by reflected light, exhibit a distinct metallic sheen. *Escherichia coli* is usually inhibited completely. Occasionally a strain is encountered which develops small black, brown or greenish colonies. This color is confined entirely to the colony itself and shows no metallic sheen.

Following the development of a satisfactory medium, a series of recovery rate studies were made using tap water, river water and sewage, all polluted by *S. typhosa*. It has been found that the size of the sample that can be examined is governed by the turbidity of the specimen and the total bacterial population that will grow on the medium. The procedure will isolate approximately 50 per cent of *S. typhosa* present when the sample contains between 10 and 100 of these organisms. Excessive numbers of *S. typhosa* colonies, other colonies or both on the filter reduce the recovery rate. Extreme crowding changes the appearance of the typhoid colony so that it is no longer recognizable by inspection.

Summary

1. The molecular filter method is useful for the enumeration of bacteria in relatively clear water with high or low bacterial densities and in turbid waters with high bacterial populations. Its value has not been demonstrated for samples with high turbidity and very low bacterial density.

2. A modified Endo broth and technical procedure for the differentiation of coliform organisms on the molecular filter has been developed at the Environmental Health Center in Cincinnati.

The method appears to provide an adequate test for coliform density. Further trials in several treatment plants with waters of different degrees of pollution, varying chemical composition and treatment methods are desirable.

3. It has been demonstrated that *S. typhosa* can be isolated from samples of water by use of the molecular filter and a bismuth-sulfite medium.

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The objective of the Metropolitan Water Dist. staff in its recent work with the molecular filter was not to develop new media, but rather to utilize presently known formulas and to compare the quantitative results obtained by the molecular filter method with those obtained by *Standard Methods* for the bacteriological examination of water. Two media were tried in these studies: [1] the modified Gassner broth described by Dr. Goetz; and [2] a modified Endo broth similar to that referred to by Dr. Kabler.

Initially, in order that a proper technique might be developed and filters showing typical coliform colonies might be obtained, various dilutions of pure cultures of *Esch. coli* in sterile, distilled water were passed through the molecular filters, modified Gassner broth being used as the nutrient. Excellent results were obtained, the well-defined colonies showing typical coliform characteristics described by Dr. Goetz.

On the basis of these encouraging results, it was decided that raw Colorado River water should be tried. Profuse growths of noncoliform organisms were obtained on the filter, but no typical coliform colonies appeared. As the M.P.N. index for raw Colorado River water is very low, however, and as positive tests are obtained rather infrequently, the absence of typical coliform organisms on the filters was not unexpected. Samples of raw water were then inoculated with various dilutions of pure cultures of *Esch. coli,* filtered through molecular filters and incubated over pads containing modified Gassner broth. Again no typical *Esch. coli* colonies were found, although the filter was covered with numerous colonies of noncoliform type. Furthermore, these colonies were not well-defined as had been the growths obtained from pure cultures in distilled water, but to a marked extent had coalesced through spreading. As the physical structure of the molecular filter was such that spreading would normally be discouraged, some explanation for this anomalous behavior was sought.

It had been observed earlier that, immediately after a sample of raw water was filtered through a molecular filter, a measurably thick disk of yellowish material was left on its surface. This was the organic and other extraneous suspended matter which was removed from the water along with the bacteria. Apparently this film was an

important factor in the spreading of the colonies, for when it was not present (in filtering cultures suspended in distilled water) well-defined colonies could always be obtained. It was further observed that incubation over a towel saturated with water, as described by Dr. Goetz, resulted in the collection of droplets of water upon the film of suspended matter and more pronounced spreading in those areas.

In an effort to overcome the difficulty, incubation over a dry towel was tried to see whether elimination of condensation on the filter disk would reduce or eliminate the spreading and coalescence of the colonies. It did. Subsequent tests during which incubation over a dry towel or over dry blotting paper was used confirmed that spreading could be satisfactorily controlled by this modification in technique. Whether this will prove to be true when other waters containing suspended matter are examined by the molecular filter method is not known, as this procedure was used only with filters through which raw Colorado River water had been passed.

Even with dry-towel incubation, however, repeated tests with raw water inoculated with coliform organisms prior to filtration yielded only one filter disk that exhibited typical coliform colonies. This led to the conclusion that the modified Gassner broth was not sufficiently inhibitory to noncoliform organisms and that these by sheer numbers prevented the development of typical coliform types.

The use of modified Gassner broth was thereupon abandoned, and tests with a modified Endo broth were initiated. Quite unlike the Gassner medium, the Endo inhibited the development of not only many of the noncoliform organisms but of some of the coliform organisms as well. This was indicated through parallel tests wherein the counts on a molecular filter were compared with plate counts prepared from the same sample of raw water inoculated with *Esch. coli*. It was found that critical adjustment of the ratio of dye to broth and in the amount of sodium sulfite incorporated in the medium was necessary before satisfactory results could be obtained. Although a number of filters showing well-defined colonies with the typical *Esch. coli* sheen were obtained, the optimal ratio of ingredients in the Endo broth to give 100 per cent recovery of the coliform organisms introduced was not determined before the supply of molecular filters on hand was exhausted. For this reason, no quantitative comparisons of statistical value between the molecular filter method and standard methods could be made.

In the light of the relatively limited investigations completed by the Metropolitan Water Dist. staff to date, it appears that the molecular filters may, by the absence of a typical sheen on the filter when Endo broth is used, ultimately prove to be satisfactory in showing within 24 hours or less the absence of coliform organisms in Colorado River water. Whether or not the presence of coliform organisms in a sample can be established from a single incubation with presently known media is questionable. It appears that neither the modified Gassner nor the modified Endo broths tried by the district staff will serve this purpose, since confirmatory tests may be required following the development of a presumably typical sheen on the filter. More widespread investigations by a large number of laboratories will probably lead to the development of media and tech-

niques which will permit the maximum exploitation of the very promising potentialities of the molecular filter method for the bacteriological examination of water.

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On the basis of recent evidence it appears reasonably certain that membrane filters have approached a degree of refinement that suggests their extended application. Advances in fabrication and performance noted in Dr. Goetz' article are developments which indicate that further consideration of their nature is definitely warranted. Methods of effecting bacterial concentration by filtration and other means have been employed previously, but certain imperfections and lack of simplicity in operation restricted their use more or less to nonroutine applications. Moreover, they were not readily adaptable to large-scale standardized tests.

It is probable that the improvements noted in Dr. Goetz' paper will remove certain limitations to the routine use of membrane filters and enhance their utility for investigative techniques. Whether these and similar improvements in membrane filters and means and devices used in conjunction with them will satisfy the demands of standard practice under varied situations with all waters is a matter that could generate considerable conjecture. It is less likely that possible limitations will apply to nonstandard applications to the same degree.

Attempts to devise methods for the examination of potable waters involve considerations other than the function of the membrane filter itself. On the one hand there is concern with the mechanics of bacterial concentration and on the other, with the numerous aspects of bacterial analysis. This enlargement of scope is inevitable when it is considered that modifications of many established procedures might be combined with the molecular filter technique. Successful application may depend upon how effectively these procedures can be used with the filter. Too, the effect of the physico-chemical nature of the molecular filter on phenomena associated with diffusion, for example, no doubt plays an important role in any aspect of the initial stages of bacterial analysis for which it is used.

Despite the apparent advantages afforded by the concentration of bacterial cells in providing simple and rapid methods for the examination of potable waters, there are, as in conventional testing, other factors which must be considered, such as the physical and bacterial nature of a specific water and the variation among waters. Difficulties may be caused by both the qualitative and quantitative aspects of the bacterial flora in some waters. The formulation of differential media providing a clear, characteristic reaction with index coliform organisms is one such problem. This factor is recognized as one of major importance by several other workers (1). In this relation, the introduction of phenomena associated with diffusion of media components through a membrane might conceivably add to the difficulties. If the density of bacteria in 1 ml. of water is too low to make practicable estimations of total count on solid plating media, concentration methods are of definite value. In the estimation of coliform density, however, combina-

tions of circumstances may result in the presence of but few typical coliform index organisms although extraneous bacteria are relatively numerous.

These and many other fundamental considerations should not be disregarded in any logical approach to the evaluation or adaptation of the molecular filter to a particular type of test with a given water. Investigations to develop means and procedures supplemental to the use of the filter are also indicated. One need is for a degree of bacterial identification commensurate with the requirement for a specific type of analysis.

As it is generally recognized that variation in waters and attendant factors have impeded development of more efficient methods of bacterial analysis, it appears that the evaluation of the molecular filter technique and its many aspects, especially as employed for standard applications, should be made under as many conditions as practicable. This evaluation should be done expeditiously. There is considerable evidence to indicate that regional bacteriological problems should be considered.

Investigation of various methods for improving routine and other forms of bacterial analysis have been in progress for several years at the laboratories of the Dept. of Water and Power (2). The initiation of these studies was prompted in part by testing difficulties arising from characteristics of the bacterial flora in waters of the Los Angeles system. It became evident in the course of this work that improved bacteriological procedures were required not only for routine testing but also for survey methods useful in the solution of water quality problems. Many conventional methods, employing differential plating techniques and customarily used concentration methods, proved either impracticable or too time-consuming and laborious for this purpose. Thus, the opportunity to use molecular filters in the attempt to solve these problems was welcomed, particularly from the standpoint of developing a satisfactory emergency test.

Evaluation of Basic Merits

Results obtained in the first phase of the investigations with the molecular filter suggested substantial agreement with some of the more fundamental merits ascribed to bacterial concentration with such filters—that is, reliability of detection, complete bacterial retention and optimum conditions for growth. Samples consisted of preparations of sterile, distilled water into which suspensions of microorganisms were inoculated. Virtually all organisms used were typical and atypical coliform and related types known to predominate in isolations made in standard practice. These studies were a logical preliminary to those using raw or distribution system samples. The excellent colonial development and quantitative results achieved with prepared samples under the conditions of these experiments supports several of the views expressed in the Dr. Goetz' article.

Bacterial Retention

Probably the best experimental evidence provided, other than actual observation of colony development, was that demonstrated by bacterial retention. Parallel studies were conducted in which replicate counts of nutrient agar plates were compared with molecular filter counts. A recovery index of 1.019 was obtained as the average for a number of series. Bacterial re-

tention was demonstrated to be virtually complete. Similar results were obtained with prepared samples when enterococci were employed as "index" organisms.

Conditions for Colony Growth

Colony development adequate for counting and subculture was demonstrated with all modifications of media customarily used for the examination of water. This was also true of special media such as the modified Gassner type noted in Dr. Goetz' article (p. 964). These results were obtained within a range of 8 to 16 hours at an incubation temperature of 37°C.

Quantitative results also appeared to substantiate the claim that bacterial cells are deposited on the surface rather than in the pores of the membrane. Pore size and other characteristics of the filter were apparently proper for retention and development of the viable deposited cells.

That satisfactory conditions for multiplication on the filter surface had been met was further indicated by the consistency in the uniformity of colony size with a given organism. In addition, nutriment diffused through the filter screen and was utilized. The apparently suitable conditions were also evidenced by the rapidity of colony development. Although 16 hours' incubation at 37°C. was required for virtually complete recovery, colonies were often visible within less than 12 hours.

Essentially, this varied evidence is related to the assertion that concentration of organisms in a highly dispersed state makes their detection more reliable or that conditions on the membrane are optimum for bacterial multiplication. Significant factors in the above relation were noted by Dr. Goetz. If the effects of such properties as lack of cross-diffusion are appreciable, some cultural advantages should be realized. In standard lactose enrichment, for example, the mixed flora of the sample are exposed to varied biological mechanisms. Under certain conditions coliform index organisms may be inhibited by antibiotic substances elaborated by antagonistic organisms. Moreover, every opportunity is afforded for synergistic and other mechanisms to exert their undesirable effects. Isolation of organisms upon which the index is based depends upon their survival at this critical stage. The absence of cross-diffusion should prevent or minimize the effects associated with conditions in liquid or semiliquid media since multiplying bacteria are believed to be in contact with nutrient only within individual colonies.

Under some adverse conditions of a physical or physico-chemical nature, the filter surface might not provide an optimum environment for the multiplication or even survival of viable organisms deposited. Although there was no evidence of this condition in the Los Angeles exploratory studies with prepared samples, extensive studies on the nature of bacterial multiplication on molecular filter surfaces appear indicated in view of the variety of conditions that might be encountered with different waters.

Combination With Other Techniques

The ease with which colonies can be subcultured from the molecular filter surface unquestionably is an important asset of this technique. Enrichment and subsequent exposure to differential media followed by transfer of colonies for further identification effects a substantial reduction in time and manipulations. Moreover, this procedure af-

fords numerous opportunities for combinations with other techniques.

Cognizance should be taken, however, of the possibility that colonies will consist of mixtures. As noted in investigations of the Dept. of Water and Power several times when conditions were not optimum, such mixing often occurs with some coliform organisms and other bacteria found in certain waters.

Evaluation of Incidental Methods

It is apparent that substantial deviation from standard practice is indeed required in the laboratory techniques for culture on molecular filters. Thus, it can be reasonably expected that considerable effort will have to be directed toward alteration and refinement of existing procedures and development of new methods to suit each type of application. Several such techniques are included in a later part of this discussion.

The Los Angeles investigations have for the most part resulted in findings that have verified claims for economy in use of media and simplicity of manipulative procedures. Reductions in the requirements for glassware and incubation space were also effected.

Sterilization of nutrient pads and membrane filters with ethylene oxide proved satisfactory. There was no evidence of contamination in any of the experimental work.

Heat sterilization of the stainless steel filter components with a burner flame proved somewhat unsatisfactory. Even after considerable application of heat, droplets of moisture sometimes contained viable microorganisms. The 10- to 15-minute period required for cooling of equipment proved excessive even for investigative work. The solution to this problem, especially for routine work, is use of sufficient units so that a given number may be autoclaved or carefully sterilized by other means while a series of samples are being filtered with another set.

For survey or expeditionary work in the field involving large or small numbers of samples, the molecular filter technique would unquestionably offer advantages over present methods. For routine uses, however, in which large numbers of samples are being taken under varied conditions over an extensive distribution or storage system, certain problems are indicated. Proper sterilization of filter equipment under varied field conditions might prove difficult. This may prove especially important if a sample with a relatively high coliform count should precede one with a low count.

In extensive systems, the time factor for incubation must be considered. Often sample runs extend over five hours or more. If incubated immediately, progressive samples would reach their optimum period for enumeration and subculture at widely separated intervals. Culture failures from accidents incidental to transportation and handling might prove excessive. For analyses involving a few samples, such as those in small water systems, these difficulties would probably not be experienced.

Evaluation of Media

It was recognized at the outset of efforts to develop a rapid emergency test that the major problem involved was the development of proper media. The requirement for a highly selective and differential medium was critical in this proposed application, because it was desirable to obtain maximum correlation between cultural appearance of the colonies and the presence in

them of lactose-fermenting typical coliform organisms. Thus, under extreme emergency conditions, samples demonstrating the presence of coliform suspects would be subject to suspicion within the 16-hour incubation period. This would satisfy the aims of the ideal test for simplicity, rapidity and the eliciting of a clear, characteristic coliform reaction. Information on samples indicating pollution could be available while further identification would proceed if required.

Virtually all established media used in the examination of water were subjected to controlled experimentation. As in the studies on the fundamental merits of the molecular filter method, initial work was performed with prepared samples.

Though colonial development proved satisfactory with all media, many were found unsatisfactory in their standard formulations. Survival of atypical coliform and noncoliform organisms indicated that media used with molecular filters had the same general limitations as all media containing inhibiting agents.

The EHC modification of Endo medium proved the most satisfactory for the estimation of coliform density, but was not entirely suitable for the bacterial flora of the waters tested. Coliform organisms of questionable sanitary significance, related types and some spore formers were not completely inhibited. Investigations are continuing on incorporation of inhibiting agents for this purpose.

As a result of the studies of these media in general, it must be emphasized that comparisons with the agar plate counterpart should be approached with caution. Findings by the Dept. of Water and Power are in agreement with those obtained at the Environmental Health Center on this point.

Media containing dyes such as eosin and methylene-blue colored the molecular filter. The typical sheen reaction characteristic of *Esch. coli* was not exhibited. Apparently, basic dyes are adsorbed by the filter screen. In addition, media containing pH indicators did not produce characteristic reactions on the filter. Although filters were often tinted, colonies appeared culturally undifferentiated and lacked visual contrast.

In making estimations of total bacterial density with prepared samples, it was found that 2,3,5-triphenyltetrazolium chloride always provided excellent visual contrast. The red compound produced by the reductase activity of the bacterial cells facilitated enumeration of colonies and subculture from the white molecular filter (3, 4). It was found that this salt in 0.04 per cent concentration (total) could be incorporated in media which contained customarily used inhibitory and selective agents. It was used successfully for visual contrast with media containing sodium azide for the selective isolation of enterococci. Though proved useful in estimations of total density from prepared samples, reductase indicator medium did not prove satisfactory with distribution system waters. The absence of inhibiting agents allowed the development of spore formers, and bacterial growth on the membrane consisted of a mat of ill-defined colonies. Colonies were confluent to the extent that enumeration was virtually impossible. Preliminary studies failed to demonstrate inhibition of organisms by the tetrazolium salt in concentrations used.

With these waters the modified Gassner medium noted by Dr. Goetz,

though productive of good colony development, proved unsatisfactory for the estimation of coliform density. Spore formers, atypical coliform organisms and extraneous organisms developed to such an extent that colonies became confluent. These results were obtained with one of the modifications of Gassner medium alone, rather than combined with redox indicator.

There is a high incidence of organisms producing acid from lactose and slow lactose fermenters in these waters. These produced blue colonies no different in appearance from lactose fermenters. Only a small percentage of organisms failed to develop or were differentiated by their pale yellow appearance. Innumerable precise identification studies of blue colonies failed to reveal the presence of lactose-fermenting coliform organisms.

Differentiation by techniques in which incubation is interrupted for transfer of molecular filters to pads containing selective nutrients suggests employment in special procedures. Because of the requirement for simplicity in standard routine practice, however, appreciable interruption of incubation might prove impracticable. This would be especially valid under normal operating conditions in which overnight incubation of large numbers of samples is involved.

The logical exception to this objection is the transfer of filters after two hours' incubation from an enrichment medium having no inhibitory properties to differential media used in the estimation of coliform density. This transfer has been shown to be essential for a quantitative result of reasonable accuracy, as toxic properties of selective agents towards bacteria in general are more profound at this critical stage of multiplication.

Experiences With Distribution System Waters

The principal difficulties encountered in attempts to apply molecular filters to bacterial analysis arose with that portion of the investigation in which treated distribution system water was used.

For the most part natural waters of the Los Angeles system, including simple chlorinated distribution supplies, are characterized by the following: [1] presence of appreciable amounts of suspended organic and other material; [2] relatively low density of typical coliform organisms; and [3] relatively high density of spore formers, atypical coliform and related types of organisms. The results of these early studies indicate that this condition represents a significant and unfortunate combination of circumstances as far as certain aspects of bacterial concentration are concerned.

Suspended Material

One of the outstanding advantages offered by the molecular filter technique is the opportunity afforded for concentration of coliform organisms from waters with a low density of index organisms. Obviously, appreciable turbidity resulting from organic and other detritus deposited on the membrane with bacteria can interfere with colonial development.

In recent work reported by the Environmental Health Center at Cincinnati, it was found that similar results were obtained in the estimation of total bacterial density—that is, filtration was not successful on samples with extremely high turbidity and very low bacterial density. The filter method is, however, recommended for estimations of counts in relatively clear water with high or low bacterial densities.

In extreme circumstances, suspended material exerted considerable effect. The speed of filtration was reduced appreciably by sample volumes in excess of 250 ml. Depending upon the source of the water, the deposition on the filter surface consisted of colored sediment usually in different intensities of green or brown. In contrast to this effect, distribution system samples of 100 ml., causing moderate discoloration of the filters, were usually filtered in less than 20 seconds.

Effects on colony development were noted. Control filters run in parallel with the filter run demonstrated that, when sediment was appreciable, adjacent colonies on the incubated molecular filter were more likely to be confluent. Examination under a hand lens showed that moist particulate matter contained extensions of colonies where bacterial growth had occurred. Color of colonies appeared less intense in media containing indicators or substances providing visual contrast. It is probable that the mat of suspended material interfered with diffusion or combined with these substances. As no reduction in colony size was evidenced, it might be inferred that access to nutrients was not reduced. The watery appearance of colonies suggested that excessive moisture retained by the deposit of plankton might have accounted to some degree for increased confluence of colonies.

Some of the more undesirable effects were: [1] inaccurate estimations of bacterial density; [2] interference with subculture of colonies; and [3] mixtures of organisms within colonies. Less tangible than these are effects which might be exerted upon selective, inhibitory and other agents employed in media formulations. These, as well as possible antibiotic activity in the deposited layer, must remain matters for conjecture at the present.

Low Coliform Density

Essentially, the effect of low coliform density on the sample volumes required for detection of viable organisms and a representative count presents a problem. Larger samples would increase amounts of suspended materials.

A related problem arises from the necessity for determining the average range of coliform counts in order to establish the sample volume in routine quantitative estimation of the coliform group.

High Noncoliform Density

The presence of relatively high numbers of atypical coliform organisms, spore formers and noncoliform organisms produced some undesirable results. In estimations of total density, using noninhibitory media, spore formers produced an ill-defined mat of growth and confluent colonies over the surface of the filter. Counting of colonies was virtually impossible under these conditions.

When media having selective properties were employed, development of spore formers was materially reduced or eliminated, depending upon the medium and the particular sample. The survival of many bacteria closely related to the coliform group, however, still posed a problem. Adjacent coliform and noncoliform colonies became confluent, so that mixtures were obtained on subculture. Some of these organisms were not inhibited by the EHC modification of Endo medium. Although this medium proved the most promising for the estimation of coliform density, it was not completely successful with the waters used in the Los Angeles experiments.

It appears that application of the molecular filter method to the estimation of coliform density in relatively clear waters, or those normal to certain phases of water treatment plant control, would present fewer problems than with the natural and treated distribution system waters used in these studies.

Use of Bacteriostatic Agents

Selective and inhibitory agents used in established media were incorporated into various nutrient formulations to reduce the incidence of extraneous organisms. Studies included combinations which might prove useful in eliminating only spore formers or some fraction of the bacterial flora and those best suited to differential media employed for the estimation of coliform density. In addition to the more customary substances, such as lauryl sulfate, sulfanilamide in 0.01 per cent concentration was tested.

Although the degree of effectiveness of each agent was not quantitatively determined, findings suggest that they can be employed to increase the efficacy of initial isolation subsequent to enrichment. There were no indications that any agent tested failed to exert the desired effect. Some results did indicate that usual concentrations might not be effective. As with other media components, however, caution should be exercised by avoiding comparisons with their use in liquid or semiliquid nutrients. Investigations of the precise mechanisms by which nutrients and other substances reach organisms deposited on the upper surface of filter screens are indicated. The possibility of increasing the vigor of all organisms on a molecular filter through the use of more concentrated nutrients should be considered.

Combination With Microtechniques

In view of the limitations of existing differential media in establishing with certainty the lactose-fermenting ability of coliform organisms, it was evident that colonies on molecular filters would have to be further identified. This necessity would apply to analyses comparable with present standard practice, precise survey techniques and others, except those of an emergency nature. In waters having flora characterized by predominance of *Esch. coli,* these requirements would be less critical. Correlation studies might be used to establish cultural appearance on a molecular filter with ability to attack lactose within prescribed limits, so that the results would be satisfactory for routine applications. Because of the multiplicity of atypical coliform and related types of organisms occurring in the Los Angeles waters, however, confirmation appeared to be indicated. In order to retain the rapidity of examination afforded by bacterial concentration and culture in place, the feasibility of combining microtechniques with the molecular filter scheme of analysis was explored. Briefly, such methods involve the use of relatively large amounts of inocula and low volumes of preincubated media. Use of these techniques to effect rapid biochemical identification have been reported by various workers (5, 6).

Single colonies were transferred from the molecular filter after 16 hours or less of incubation to preincubated lactose broth, Eijkman broth, and media used for biochemical tests, such as those for the IMViC series. Readings were obtained in four hours using *Esch. coli* in prepared samples. Runs made with distribution system waters indicated the use of this method for con-

firmation of coliform suspects if mixtures due to confluence of colonies were not present. Preliminary studies have not established whether single colonies always provide sufficient inoculum.

The above possibility for use of a procedure combined with the molecular filter technique exemplifies the value of this method in permitting colonies to be visualized, enumerated and transplanted from the surface of the filter screen.

Direct Biochemical Testing

A variation of the above technique, though adaptable essentially to nonroutine use, was a direct indole test. Indole-positive and indole-negative strains of *Escherichia* were filtered from prepared samples. The membrane was incubated for 12 hours using the usual tryptone medium. The filter screen was removed from the pad and dried over a microscope lamp after which it was flooded with Kovacs' reagent in a small Petri dish. Colonies of indole-positive organisms immediately exhibited a halo of the characteristic red color.

Adaptability to Special Methods

The nature of these and similar diverse applications suggests that molecular filters may find wide use in investigative procedures. This possibility is occasioned by several factors, including the greater amount of manipulative activity allowable in precise qualitative work and the opportunity their use provides to circumvent certain difficulties. In routine analysis, for example, there is insufficient time to utilize means of avoiding limitations imposed by variations in the flora and physical nature of certain waters. The employment of prepared samples and the flexibility afforded by dilution of high-count waters facilitates the use of special methods. The reduction in time realized by concentration and initial culture on molecular filters permits greater testing frequency and more extensive use of precise techniques within a given period.

It is well established that, in certain waters, routine bacteriological findings often do not correlate with sanitary quality as determined by surveys and more precise bacterial analysis. Recourse to such tests is often indicated under these circumstances. In the writer's experience these tests have proved valuable in effecting sanitary control and in solving varied water quality problems. At present, however, such methods cannot be exploited to the fullest extent because of economic considerations. Reduction in time and materials which might be effected through use of molecular filters should make such analyses more feasible. In the opinion of the writer, employment of molecular filters suggests an opportunity for the improvement of survey techniques. Similarly, procedures used in water purification and sanitation research should benefit.

The initial saving in time afforded by concentration and culture in place provides an excellent opportunity to use some of the techniques for determination of sanitary quality which are now confined to investigative work. This point should not be disregarded because it suggests the introduction of a higher degree of qualitative testing. Heretofore such analyses have been virtually precluded because of time limitations imposed by the long period required, even for gross identification in routine practice. It may well be that in the future the maintenance of adequate sanitary quality will demand em-

ployment of more precise techniques because of additional knowledge concerning organisms considered of importance as causatives of enteric disease.

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Safety Practices

In the June 1951 Journal (Vol. 43, p. 423) there was presented a task group report on Safety Practices. The report used the National Safety Council frequency and severity accident rates for utilities, as developed for 1949. The 1950 accident rates are now available and the two years may be compared to determine how water utilities are progressing in safety:

Utility	Frequency Rate		Severity Rate	
	1949	1950	1949	1950
Communications	2.14	2.05	0.15	0.12
Electrical	14.02	11.96	2.37	1.96
Gas	17.92	16.03	0.99	0.79
Water	33.00	25.50	0.90	1.05

Frequency rates for 1950 are below the 1949 rates in all four utilities while the severity rates are down for all utilities except water, which, instead, showed an increase. The reduction in the frequency rate for water utilities might be expected on the basis that the 1949 rate was so high in relation to other utilities that it almost had to decrease. The 1950 frequency rate is still high.

The increase in the water severity rate in the face of declining rates for other utilities would indicate a lack of a concerted effort in the application of safety practices. The task group report substantiates this opinion.

Here is a direct challenge to our industry.

Water Hammer Control

By S. Logan Kerr

A paper presented on Sept. 21, 1951, at the Pennsylvania Section Meeting, Philadelphia, by S. Logan Kerr, Cons. Engr., Philadelphia.

THE control of water hammer is the subject of much speculation and of widely differing opinions. Many engineers and operating men, as well as a number of manufacturers, associate water hammer with the mechanical slamming of a swing check valve, believing that, if there is no noise, there is no water hammer. In their cushioned checks, cone type or other forms of valves that do not slam mechanically, many manufacturers have claimed a panacea for water hammer. Far as it is from the truth, this seeming solution—no noise, no water hammer—has lulled many engineers into thinking that their problems were over, only to awaken them later by pulling their pumping main apart at its joints or even splitting it wide open.

To control water hammer one must first understand what it is and what causes it and, then, determine the magnitude of the surge and its relationship to the strength of the pipe at all critical points. Much mystery has surrounded the solution of water hammer problems, probably because of the complex theory of wave motion involved and the lack of time or opportunity for most engineers to study the details or to perform the calculations. As a result, a number of approximate formulas have been developed, some of which are good within limits, but most of which are dangerous to use. The variations from the true values range from 35 per cent below to 500 per cent above. Table 1 compares a number of such approximate formulas, found in textbooks and handbooks, with the well proved elastic wave theory.

Variations like these in computed surge values led the American Society of Mechanical Engineers in 1931 to sponsor a committee on water hammer. Other societies, including the American Society of Civil Engineers, the Engineering Institute of Canada and the American Water Works Association also participated in this activity, which produced two symposiums (1933 and 1937) on the subject in its various aspects (1, 2). Much interest was aroused and there have been many other discussions of the matter by these and other societies during the past 20 years (3–9).

As demonstrated in Fig. 1, field tests (1, p. 29) have confirmed the mathematical analyses based on the elastic wave theory of Joukovsky (10) and Allievi (11) even when a complex system, with many changes in thickness and diameter, was involved. A simpler approach, now in use, employs a graphical method of analysis that permits the solution of some problems which were previously impossible of rigid analysis (4, 6). The graphical method also permits taking into account the variable rates of valve

movements and other such complicated factors. The primary problem, though, is one of presenting the practical aspects in simple form, to enable the average designer, purchaser or operator of hydraulic machinery to know when a situation is dangerous or when reasonable water hammer pressure allowances can be used with safety. Although there is no complete answer to this difficulty, it may be helpful to discuss generally some of the fundamental relations that determine water hammer pressures, omitting, as far as possible, the complicated formulas involved.

TABLE 1

Comparison of a Number of Approximate Formulas for the Determination of Pipeline Surges

EXAMPLE: length (L), 820 ft.; velocity (V), 11.75 fps.; time (T), 2.1 seconds; head (H_0), 165 ft.; wave velocity (α), 3,220 fps.; critical time $\left(\frac{2L}{\alpha}\right)$, 0.509 seconds.

Name of Formula	Formula	Max. Pressure Rise, *ft.*	Percentage of Max. by Elastic Wave Theory, *per cent*
Vensano	$h = \frac{2LV}{gT}$	285.0	129.6
Warren	$h = \frac{LV}{g\left(T - \frac{L}{\alpha}\right)}$	162.3	73.8
Johnson	$h = \frac{LV_0}{2g^2H_0T^2}[LV_0 + \sqrt{4g^2H^2T^2 + L^2V_0^2}]$	216.0	98.3
Fanning	$h = \frac{LV}{gT}$	142.5	64.8
Talbot	$h = 2.31V\sqrt{\frac{1}{1 + \frac{Kd}{Ee}}}\sqrt{\frac{WK}{144g}}$	1,175.0	535.0
reduces to:	$h = \frac{\alpha V}{g}$		
de Sparre	$h = \frac{2LV_0}{gT}\frac{1}{2\left[1 - \frac{LV_0}{2gTH_0}\right]}$	251.0	114.2
Elastic Wave Theory:			
a. Detailed calculation—equations of Allievi, Gibson, Quick and Gibson arithmetic integration		219.89	100.0
b. Charts by Quick and Allievi		219.9	100.0

The physical factors of a hydraulic system, such as length, diameter, materials and thickness of the pipe, the head, quantity of flow and friction

losses, can all be established from the design. Information on valve, pump or turbine characteristics can be obtained from the manufacturers with not too much difficulty. Thus, there remains only the application of some specialized knowledge to arrive at the solution of a water hammer problem. Several fundamental examples will be discussed and the graphical determination of the surge pressures demonstrated for them.

the square-root relationship between head and discharge. If friction is neglected in this example, the static head can be represented as a horizontal line through the vertical axis at a point corresponding to 165 ft.

The static-head line and the steady-state head-velocity relationship intersect at Point 1, which represents the normal operating point. It may be assumed that the rate of cutting off the flow is uniform in time and that

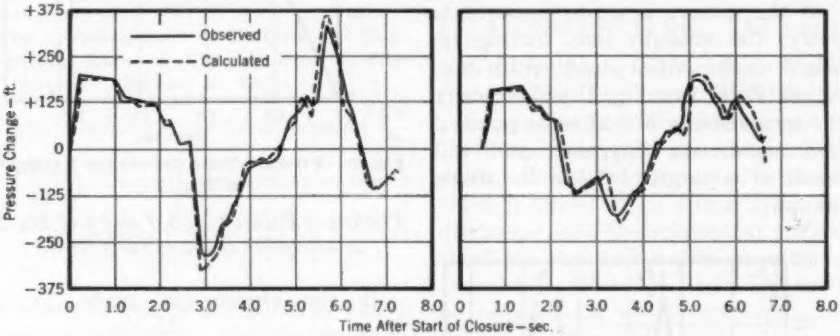

Fig. 1. Comparison of Theoretical and Field Test Pressures

Penstock 4,550 ft. long included 663 ft. of 61-in., 527 ft. of 55-in., 1,872 ft. of 49.2-in. and 2,071 ft. of 43.3-in. pipe. Thickness varied from 0.375 in. at top to 1.688 in. at bottom. Flow of 15.5 cfs. stopped in 0.22 seconds.

Left: *pressure-time curves at control valve;* Right: *pressure-time curves at lower end of 49.2-in. section, 0.455*L *from valve.*

Graphical Solution of Problem

The example used for the comparison of the various approximate formulas of Table 1 can also be solved by the graphical method. If the hydraulic characteristics of a system are plotted on rectangular coordinates, Fig. 2, it is possible to show the head or pressure along the vertical axis and the velocity of flow in the conduit along the horizontal axis. Under any steady-state condition, with fixed valve opening, the relationship between velocity and head will be given by a curve (B_0) which follows the closure takes place in 2.1 seconds. The length, diameter and material of construction of the pipe give a pressure wave velocity of 3,220 fps. The critical time $\left(\frac{2L}{\alpha}\text{ seconds}\right)$ for a surge wave to travel from the valve to the intake and return is approximately 0.51 seconds. Hence, the closure will be in slightly more than four such intervals. Additional curves which represent the intermediate steady-state condition of the control valve at each unit of critical time can then be drawn (B_1, B_2, B_3 and B_4).

A further relationship between head and velocity is that surge pressure equals $\frac{\alpha V}{g}$ whenever the valve is closed in a time equal to or less than the critical time of the conduit. This relationship is represented graphically by a straight line and has a slope of $\frac{\alpha}{g}$ either plus or minus, depending on whether it is a wave of positive or negative pressure.

If the closure is made instantaneously, the straight line, having its origin at the initial steady-state condition (Point 1 on Fig. 2) will intersect the zero-velocity line at some point, 2 (not shown on diagram), and will result in a surge of 1,175 ft. above normal.

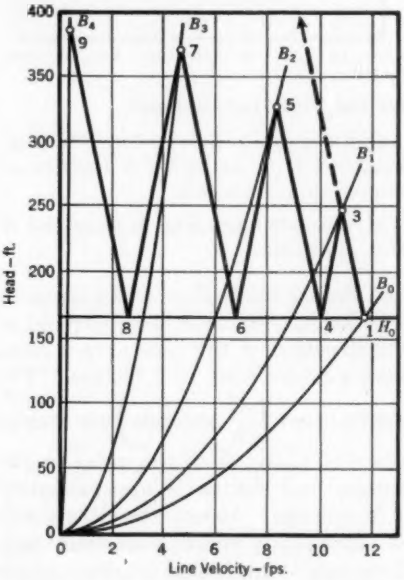

Fig. 2. Graphical Solution of Example Presented in Table 1

Hydraulic characteristics of system plotted on rectangular coordinates.

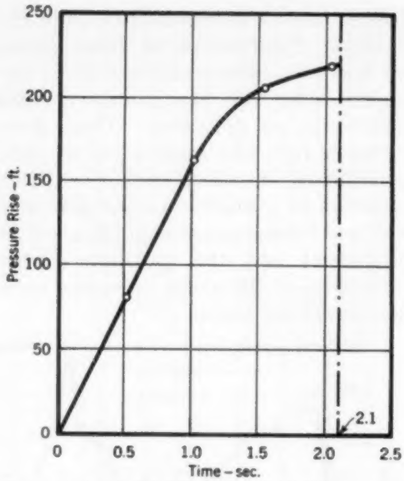

Fig. 3. Pressure-Time Curves for Example in Fig. 2

Plotting of Points 1, 3, 5, 7 and 9 of Fig. 2 to determine shape of surge wave.

If the closure is made in a time greater than $\frac{2L}{\alpha}$ seconds, the valve stroke can be assumed to be made in a series of increments each equal to $\frac{2L}{\alpha}$ seconds. In this event, the line would start at Point 1 and would interesect the next steady-state condition at Point 3. It would then be reflected to Point 4, along the line drawn with a downward slope, until it intersected the normal head line. There again, it would be reflected until it reached the point corresponding to two intervals opening under a steady-state condition, shown as Point 5. This pattern is continued until the valve is closed.

It will be noted that Points 1, 3, 5, 7 and 9 of Fig. 2 represent the pressures at time increments of $\frac{2L}{\alpha}$ seconds. If they are drawn as shown in Fig. 3,

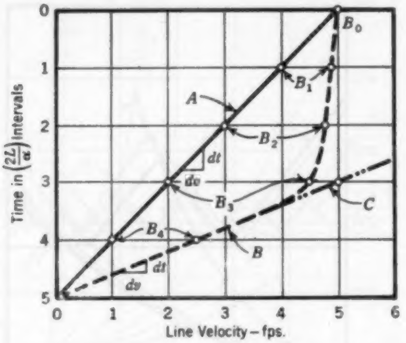

Fig. 4. Comparison of Uniform and Nonuniform Rates of Velocity Control With Respect to Time

Curve A *represents uniform control* $\left(\frac{dV}{dt} = 0.50\right)$; *Curve* B *represents nonuniform control* $\left(\frac{dV}{dt} = 1.25\right)$.

a curve in time of pressure rise above normal will result, and the shape of the surge wave can be determined. After the valve is closed, the oscillations of pressure, unless damped, will continue above and below the normal head line and can be represented on the diagram accordingly. The maximum pressure, as indicated from the graphical solution, is identical with that obtained by the use of the elastic-wave theory equations, no new element of theory being introduced.

Nonlinear Valve Movement

In making surge analyses, it is essential to have all the data on the hydraulic characteristics of the system, including information on the behavior of the valves or other devices which may be controlling flow. The usual assumption of uniform rate of flow reduction is based on two fallacies:

1. That the stroke of the valve stem cuts off area at a uniform rate.
2. That the flow through a valve is in direct proportion to the area and hence to stem travel.

In a given system, with an initial flow of 5 fps. and a shutoff rate of five intervals of time $\left(\frac{2L}{\alpha} \text{ seconds}\right)$, the uniform rate of flow reduction could be represented as Curve A in Fig. 4. The rate of change of velocity $\left(\frac{dv}{dt}\right)$ would be 0.50 fps. The graphical solution is given in Fig. 5, and the pressure-time curve, *A*, in Fig. 6, shows a rise of 60 ft. above normal.

By contrast, in actual practice, when an ordinary gate valve is closed, there is little or no effect upon the discharge until about one-half to one-third of the full valve opening is closed off. The flow then begins to be reduced far more rapidly as the valve continues toward the seat. Such a typical relationship for an

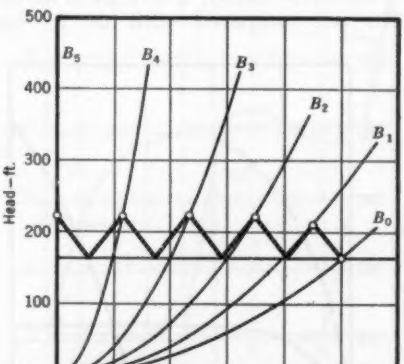

Fig. 5. Graphical Solution for Uniform Variation of Velocity With Respect to Time

Solution of problem represented by Curve A, *Fig. 4.*

ordinary gate valve is shown in Curve *B* of Fig. 4. It will be seen that the maximum rate of change of flow $\left(\frac{dv}{dt}\right)$ is $2\frac{1}{2}$ times that for uniform closure assumptions, reaching a value of 1.25 fps.

The graphical method can account for variable rates of change of flow, as the steady-state velocity relationship can be taken from Curve *B*, Fig. 4, at each interval of time. The B_1–B_5 points, shown in Fig. 7, give the corresponding relationships, and the solution follows the same procedure as with uniform flow cutoff. The pressure rises very slowly until the valve begins to cut off flow; then, after three intervals of time, the pressure rise is very much greater than it would have been if the flow rate had been cut off uniformly throughout the whole stroke.

Figure 6 shows the difference in pressure-time curves for these two examples. The rise above normal for nonuniform cutoff, Curve *B*, is about 210 ft., compared with 60 ft. for

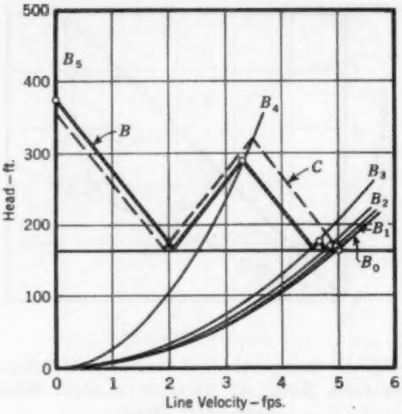

Fig. 7. Graphical Solution for Nonuniform Variation of Velocity With Respect to Time

Solution of problem represented by Curves B *and* C *of Fig. 4. Curve* B *represents nonuniform flow cutoff; Curve* C *is based on uniform equivalent time.*

uniform closure, or $3\frac{1}{2}$ times as great. Such differences can explain many pipeline failures.

In the water works and hydroelectric fields, a reasonably valid short cut is used to approximate the effect of nonuniform flow-rate cutoff. Since it is the maximum rate of change of flow that determines the maximum rise in pressure, a line tangent to this maximum cutoff rate can be drawn—Curve *C*, Fig. 4—and a so-called "equivalent time" secured. In the present example, the equivalent uniform rate would be two intervals of time rather than five. The dash lines in Fig. 6 and 7 give the graphical solution. A rise of 195 ft. above normal is indicated, compared with 210 ft. by the more precise method—an error of only 7 per cent, compared with 250 per cent by the assumption of Curve *A*.

This so-called short cut makes it possible to determine the required

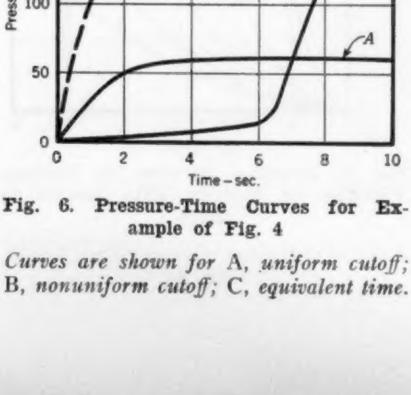

Fig. 6. Pressure-Time Curves for Example of Fig. 4

Curves are shown for A, *uniform cutoff;* B, *nonuniform cutoff;* C, *equivalent time.*

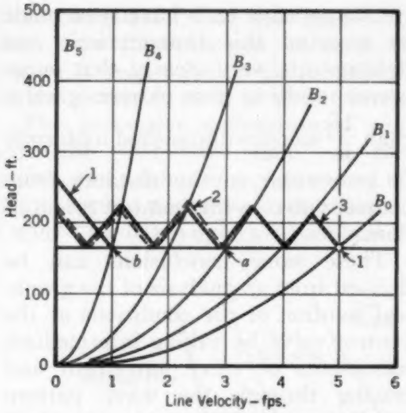

Fig. 8. Graphical Solution for Uniform Variation of Velocity With Respect to Time

Solution of problem represented by Curve A of Fig. 4 with different initial valve positions, as follows: 1—uniform closure from 20 per cent open to zero; 2—uniform closure from 60 per cent open to zero; 3—uniform closure from full open to zero.

total time of travel to limit surge pressures to permissible maximum values. The same procedure can be used with some degree of assurance on valves of other than nonlinear types. It is necessary to deduct the unseating and reseating piston travel time for cone type valves and to secure the slope of the flow-time curve for the actual plug rotational portion of the stroke.

Effect of Initial Opening

It is also interesting to analyze the effect of the initial starting point of valve closure upon the magnitude of surge pressures obtained. Closure from some intermediate point down to zero may give a much higher surge value than closing at the same uniform rate from the wide-open valve position down to zero. Figure 8 shows, for the same example as used in Figs. 4–7, Curve A, the graphical solution which indicates the relationship of the initial starting point. It will be seen that higher surge pressures result when closure is initiated from 60-per cent or from 20-per cent flow rates than when full flow is interrupted. Figure 9 gives the pressure-time curves and shows the change in wave shape as well.

When the closing time is greater than $\frac{2L}{a}$ seconds, there will be some intermediate point from which the valve can be closed to zero in exactly $\frac{2L}{a}$ seconds, and this will result in instantaneous water hammer for that smaller flow. Nonuniform valve operation can aggravate this effect.

Surge Variation Along Conduit

It is interesting to note the variation in wave form at the control gate and at intermediate points along the

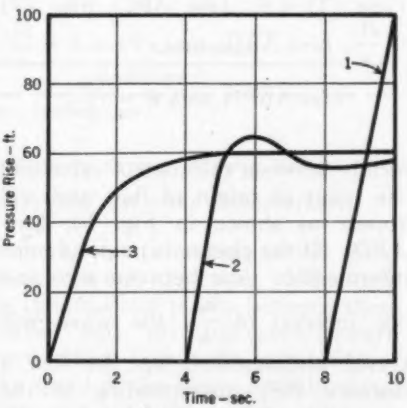

Fig. 9. Pressure-Time Curves for Examples in Fig. 8

Curves are shown for: 1—uniform closure from 20 per cent open to zero; 2—uniform closure from 60 per cent open to zero; 3—uniform closure from full open to zero.

pipeline for different rates of closure. If closure is made instantaneously, then—aside from any natural damping of the wave due to internal friction, compressibility of the fluid, or expansion of the pipe walls—this wave will travel undiminished from control valve to the point of origin of flow, and the distribution of pressure along the line will be *ABFC* in Fig. 10. If closure requires $\frac{2L}{\alpha}$ seconds or more, the surge pressure will diminish uni-

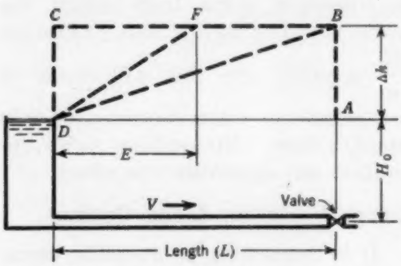

Fig. 10. Distribution of Surge Wave Along Pipeline

Time (T) = *0*, *Line* $\overline{\text{ABC}}$; *time* (T) $\geqq \frac{2\text{L}}{\alpha}$, *Line* $\overline{\text{ABD}}$; *time* (T) $> 0 < \frac{2\text{L}}{\alpha}$, *Line* $\overline{\text{ABFD}}$, *with* $\text{E} = \frac{\text{T}\alpha}{2}$.

formly between the control valve and the point of origin of flow and will appear as shown in Fig. 10, Line *ABD*. If the closure is made at some intermediate time between zero and one interval of $\frac{2L}{\alpha}$, the wave will travel undiminished up the line a distance *BF*, corresponding to the proportion of time that the closure is less than time $\frac{2L}{\alpha}$ seconds, and, from that point (*F*), will gradually diminish to zero at the point of origin of flow *ABFD*.

Comparative tests have been made to measure this characteristic and demonstrate very clearly that surge waves resulting from closures greater than $\frac{2L}{\alpha}$ seconds diminished uniformly in proportion to the distance from control valve to the point of origin of flow.

These same conclusions can be derived from an analysis of the graphical solution of the conditions at the control valve by taking intermediate increments of valve movement and tracing through the wave pattern step by step. It is necessary, then, to know the number of increments of valve movement in proportion to the distance from the control gate to the intermediate point where it is desired to investigate pressure variations.

Effect of Centrifugal Pumps

With the graphical method it is also possible, as shown in Fig. 11, to take into account centrifugal pump characteristics. If the head-velocity curves of a centrifugal pump are superimposed on the graphical diagram, a new series of steady-state operation points results. The line friction also can be indicated, and throttling-valve or control-valve characteristics added if desired. If an analysis of the surge conditions following the power failure to a motor-driven centrifugal pump is needed, the usual sloped lines, showing the transient surge-wave relationship, can be drawn and the step-by-step variation in velocity and pressure determined. If the flywheel effect of the rotating element of the pump and motor is known, the average pressure can be estimated over given time increments and the approximate increments of speed reduction for each interval of

time computed. The new speeds at such time intervals can be used to secure a head-velocity characteristic of the pump at each of those times.

The successive computations will give the "run-down time" of the pump, and a fairly complete record of what occurs under such conditions. Figure 11 is based upon a typical water made and the results published by R. T. Knapp (2, p. 683) and others, giving the head, flow and torque curves at various speeds of pump rotation, both forward and in reverse.

In the example, Fig. 11, two such curves of head-velocity are shown—CC', for backward flow with the rotor stopped, and DD', for backward flow

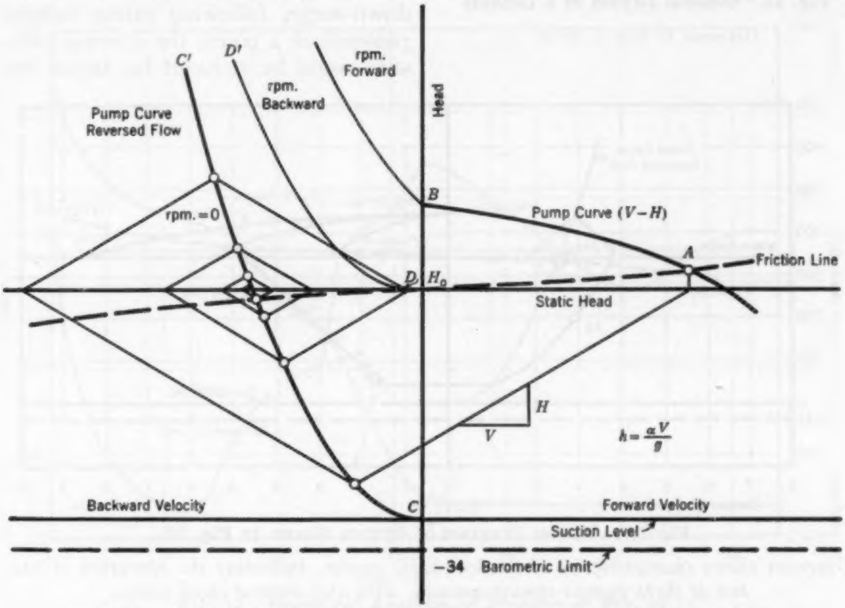

Fig. 11. Graphical Surge Diagram for Pumping System Without Valve

Use of graphical method to take into account centrifugal pump characteristics.

works installation in which the pipe friction was small compared with the normal operating pressure. It was also assumed that no check valve was present and that the pump was allowed to reverse its rotation.

As an added refinement in complex surge studies, the complete characteristics of centrifugal pumps can be considered. This feature is important if slow-closing valves or control valves are to be used. Tests have been with the pump rotating at full speed in the reverse direction. There will be intermediate points between these curves and the full-speed-forward curve which permit the calculation of the speed of the pump and the surge pressures until the system reaches a point of stability and the speed of the pump stays constant.

System With Irregular Profile

In graphical diagrams it is possible also to determine the pressures at any

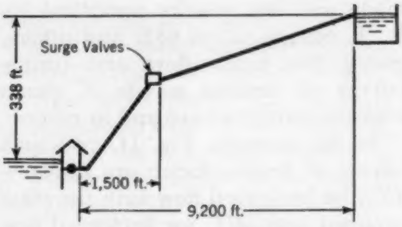

Fig. 12. General Layout of a Conduit

Diameter of pipe is 36 in.

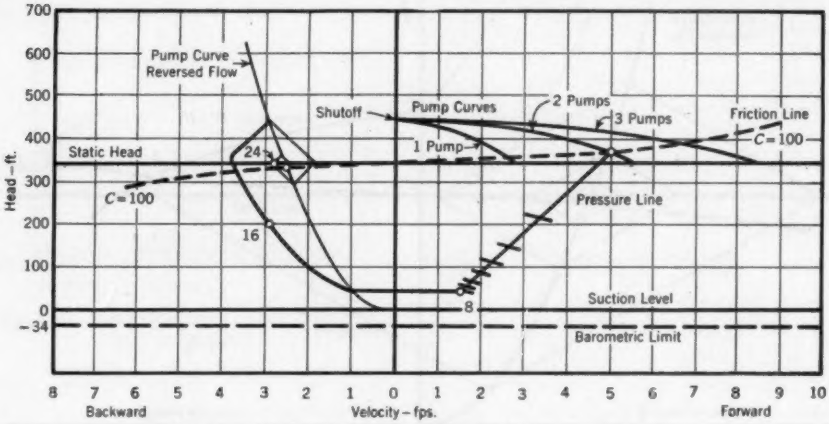

Fig. 13. Master Diagram of System Shown in Fig. 12

Diagram shows characteristics of the hydraulic system, including the operation of one, two or three pumps simultaneously, with and without check valves.

intermediate point on the line and evaluate the effect of a pipeline profile. In some situations this factor may prove to be critical. If the line is level and both the inlet and outlet are at the same elevation as the pumps, the problem will be less complex.

When water is being pumped downhill, the liquid column may "run away" from a closed valve, leaving a vapor pocket that must be refilled at a safe rate to avoid sudden surges when the pumps are restarted and the oncoming liquid column meets the column at rest. When water is being pumped uphill, the liquid column may come to rest and reverse rapidly, causing the pumps to run backward at a high rate of speed. Check valves can be slammed shut under such conditions and heavy surges experienced.

In some installations a variable gradient is followed, and high points in the line may become critical. If a down-surge, following pump failure, passes such a point, the internal pressure could be reduced far below the vapor pressure of the fluid, and the liquid column would part. Upon rejoining, the two sections might have their relative velocities changed abruptly, causing a severe surge. A complete study of one such problem, in which the parting and rejoining of the water column in the discharge line of the pump upon emergency trip-out or loss of driving power was another variable, will give a good idea of the procedure involved.

The general layout of the conduit is shown in Fig. 12. Its characteristic of length, diameter and velocity,

and the master diagram of the hydraulic system, including the operation of one, two or three pumps simultaneously, with and without check valves are shown in Fig. 13. The point at which the column parted and rejoined was approximately one-eighth the distance from the pump-house to the discharge basin, and intervals of time equal to one-eighth of $\frac{2L}{\alpha}$ seconds were utilized in analyzing this diagram. Figure 14 shows the conditions with two pumps tripped out and very gradual check-valve closure. The slowing down and reversal of the pump and the approximate steady-state conditions with the pump operating backward are all shown. The check-valve closure was at a rate sufficiently slow to prevent cutting off the backward flow abruptly and causing the pressure to exceed a predetermined value.

At a point about 1,500 ft. beyond the pumphouse, the subnormal pressure fell below the barometric limit. The water column parted at this point, the upper portion gradually slowing down, coming to rest and reversing, while the lower portion of the column continued to flow back through the pump after having reversed at a much more rapid rate. The upper column gradually picked up momentum and rejoined the lower column, resulting in an instantaneous surge pressure which was much greater than that due to check-valve closure. The resultant surge pressure, when the two columns rejoined, would be approximately 250 psi. above normal

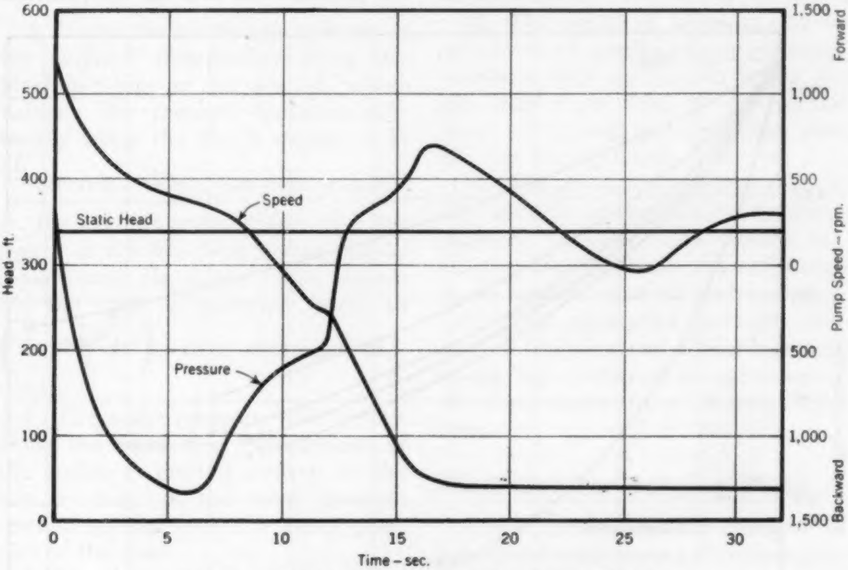

Fig. 14. Graphical Analysis of Pipeline of Fig. 12

Line consisted of 9,200 ft. of 36-in. pipe. Two pumps were tripped out and check valves operated very gradually.

if no remedial devices were installed. On this installation, some quick-opening, slow-closing air valves were utilized at the crest of the hill, to admit air to act as a cushion, reducing the rate at which the two columns were rejoining.

An analysis in advance of design indicated that a surge pressure of about 70 psi. would be experienced nearly a year previously, and the actual test values recorded under service conditions.

Basic Relationships

It may be well at this point to restate a few of the fundamental relationships in surge-wave theory (Fig. 15) which determine the magnitude of the pressure rise and its distribution

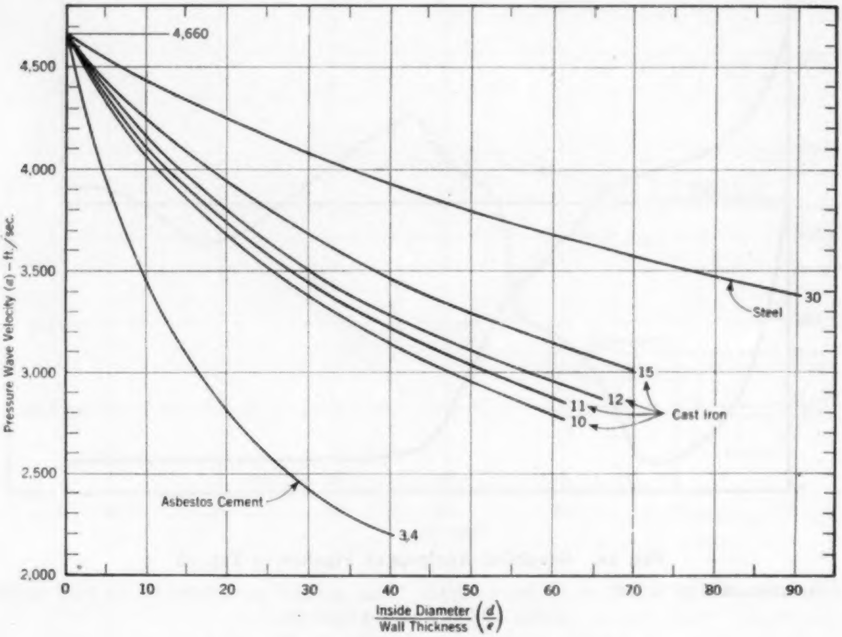

Fig. 15. Surge Wave Velocity Chart for Water

The numbers at the right of the curves represent the modulus of elasticity (E) in 1,000,000-psi units for the various pipe materials.

and would be within a safe limit of design based on the stress in the thin-wall pipe. The actual tests made in field, when one pump was tripped off, showed a surge pressure of 65 psi. Although only the operating gages were available for this check test, the readings that were secured indicated an extremely close agreement between the theoretical design values, obtained along a conduit. These comments apply to gravity flow or discharge lines from centrifugal pumps only.

1. The pressure rise for instantaneous closure is directly proportional to the fluid-velocity (V) cutoff and to the magnitude of the surge-wave velocity (α), and is independent of the length of the conduit.

2. When the flow rate is changed in a time greater than zero but less than or equal to $\frac{2L}{a}$ seconds, the magnitude of the pressure rise is the same as with instantaneous closure, but the duration of the maximum value decreases as the time of closure approaches $\frac{2L}{a}$ seconds.

3. Under the conditions in Point 2, the pressure distribution along the pipeline varies as the time of closure varies. The pressure decreases uniformly along the line if closure is in $\frac{2L}{a}$ seconds. The maximum pressure at the control valve exists the full length of the line with instantaneous closure and, for slower rates, travels up the pipe a distance equal to $\left(L - \frac{Ta}{2}\text{ ft.}\right)$, then decreases uniformly.

4. The surge-pressure distribution along the conduit is independent of the profile or ground contour of the line as long as the total pressure remains greater than the vapor pressure of the fluid.

5. For closing times of more than $\frac{2L}{a}$ seconds, the maximum pressure rise will be a function of the maximum rate of change in flow with respect to time $\left(\frac{dv}{dt}\right)$.

6. Nonlinear closures can be investigated, and the proper valve timing determined, to hold the maximum pressure rise to any desired limiting value.

7. The effects of centrifugal pumps and quick-closing check valves or control valves can be investigated using graphical method of analysis.

8. The profile of the conduit leading away from a pumping station may have a major influence upon the surge conditions. The minimum effect will be found when the line is level; the maximum, when the line is steep or when high points occur along it.

9. Parting and rejoining of the liquid column can produce extremely high pressures and may cause failure of the conduit.

10. The effect of friction can be accounted for graphically in any surge problem, and, when such losses are less than 5 per cent of the normal static or working pressure, they usually can be neglected.

11. The greater the degree of accuracy desired for the results of a surge analysis, the more the various hydraulic and physical characteristics of the system must be understood.

12. The agreement between theoretical analyses and actual field-test results has confirmed the accuracy of the elastic-wave theory in water conduits.

Check List For Pumping Mains

A few factors can be checked to indicate whether surges of serious proportions will occur in any given system, once the physical, hydraulic and operating characteristics are established. For most transmission mains supplied by motor-driven centrifugal pumps, the following twelve questions will give a clue to the seriousness of the surge problem:

1. Are there any high spots on the profile of the transmission main, where the occurrence of a vacuum can cause a parting of the water column when a pump is cut off?

2. Is the length of the transmission main less than 20 times the head on the pumps (both values expressed in feet)?

3. Is the maximum velocity of flow in the transmission main in excess of 4.0 fps.?

4. Is the factor of safety of the pipe less than 3.5 for normal operating pressures?

5. What is the natural rate of slowing down of the water column if the pump is cut off? (Will the column come to rest and reverse its direction of flow in less than the critical surge wave time of the transmission main?)

6. Will the check valve close in less than the critical time for the transmission main?

7. Are there any quick-closing automatic valves set to open or close in less than 5.0 seconds?

8. Would the pump or its driving motor be damaged if allowed to run backward up to full speed?

9. Will the pump be tripped off before the discharge valve is fully closed?

10. Will the pump be started with the discharge gate valve open?

11. Are there booster stations on the system which are dependent on the operation of the main pumping station under consideration?

12. Are there any quick-closing automatic valves used in the pumping system that become inoperative with the failure of pumping system pressure?

If the answer to *any one* of Questions 1–7 is affirmative, there is a strong possibility that serious surges will occur. If the answer to *two or more* of Questions 1–12 is affirmative, surges will probably be experienced and their severity will be in proportion to the number of "yes" answers.

General Studies for Water Hammer Control

One of the two questions which are usually asked about advance studies on surges is: How can such studies be undertaken during the design stage? The answer is simple. Once the general layout of the system has been made, the length, diameter, thickness, material and capacity of the pipe, as well as the type and size of pumps, can be established. The normal operating pressures at various points in the system can be computed and the allowable maximum pressures fixed. By this means, the margin for water hammer can be found. The design should then be adjusted to provide either safety factors large enough to withstand such conditions as might be encountered, or suitable remedial or control devices. It is important to note that there is no single magic device that will cure all surge difficulties. Only by a study of both normal operating conditions and possible emergency conditions can the proper valve-timing, surge-damping or relief devices be selected.

It is not feasible to make general recommendations on the type, size and application of surge-control equipment for all plants. Several possible solutions should be considered for any individual installation and the one that gives the maximum protection for the least expenditure selected. Surges can often be reduced substantially by using by-passes around check valves, by cushioning check valves for the last 15–20 per cent of the stroke or by adopting a two-speed rate of valve stroke. Air-inlet valves may be needed, or the preferred solution may be to use a surge damper or air chamber. In a number of plants no devices will be required to hold the pressure rise within safe limits.

It is essential to coordinate all the elements of a system properly and to ascertain that operating practices con-

form to the requirements for safety. As changes take place in the system demand, it may be necessary to review and revise the surge conditions, particularly if the capacity is increased, additional pumpage or storage is added, or booster stations are planned.

The second common question on advance surge studies is: How effective are the recommended solutions to the problem when the equipment is placed on operation? If a competent investigation was made during the design stage and the recommendations arising from it have been carried out, the final plant is almost always operated without damage due to water hammer. The agreement between the theoretical analyses, properly applied, and the actual tests of installations has been extremely close. When a surge study was not undertaken and dangerous conditions existed, there have almost invariably been serious surges, and sometimes costly damage has resulted. The time and effort spent on a surge study in advance of the final design is the least expensive means of insuring against surges. The elastic-wave theory has been completely proved in actual practice, and it remains only for design engineers to take the initiative in making these studies without waiting for serious failures to occur before installing surge-control devices.

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Correction

Tentative Standard Specifications for Reinforced Concrete Water Pipe—Noncylinder Type, Not Prestressed—C302-51T

When the text of "Tentative Standard Specifications for Reinforced Concrete Water Pipe—Noncylinder Type, Not Prestressed—C302-51T" was being prepared for publication in the October JOURNAL, the final page of the manuscript was lost, with the result that Sec. 4.3.3, 4.4, 4.5 and 4.6 were not published. These sections, the text of which appears below, are official parts of the specifications and will appear in the reprinted document:

4.3.3. The steel plate specials shall be lined and coated with mortar deposited on the surfaces by an approved method. The thickness of the mortar shall be such that the minimum cover of steel reinforcing shall be $\frac{3}{4}$ in. The mortar shall contain not less than 1 part cement to 4 parts sand, of a grading approved for the method of application used, and shall develop a 28-day compressive strength of not less than 3,500 psi.

Sec. 4.4—Curing Mortar Coatings on Specials

The mortar-coated specials shall be cured either by water spraying, by steam, or by curing compounds, as specified under Sec. 3.7 herein.

Sec. 4.5—Curves, Bends and Closures

Horizontal and vertical long-radius curves shall be formed by straight pipe in which joints are beveled. The total angular deflection for beveled pipe shall not exceed 5 deg. at any joint. Slight deflections may be made with straight pipe, provided that the maximum joint opening caused by such deflections shall not exceed $\frac{3}{4}$ in. for 36 in. and smaller pipe and 1 in. for pipe larger than 36 in. Short-radius curves and closures shall be formed by fabricated specials of either of the two types specified in Sec. 4.1.

Sec. 4.6—Openings and Connections

Manholes and flanged, spigot or bell connections for air valves, blowoffs or connections to other pipes shall be built into the walls of the concrete pipe at locations shown on the contract drawings or ordered by the purchaser. Wall openings shall be formed by welding fittings of cast steel or fabricated structural steel of approved design to a saddle plate or to the reinforcing cage of straight pipe. If required, the interior and exterior surfaces of structural steel connections shall be lined and coated with reinforced mortar as specified in Sec. 4.3.

Performance Studies on Sulfur Jointing Compounds

By Raymond B. Seymour, Walter Pascoe, W. J. Eney, A. C. Loewer, Robert H. Steiner and R. D. Stout

A paper presented on May 1, 1951, at the Annual Conference, Miami, by Raymond B. Seymour, Tech. Director and General Mgr., Walter Pascoe and Robert H. Steiner, all of the Atlas Mineral Products Co., Mertztown, Pa.; and W. J. Eney, A. C. Loewer and R. D. Stout of Lehigh Univ., Bethlehem, Pa.

DESPITE engineering skills, structures occasionally fail because of faulty design, construction or materials. Without sufficient information on any one of these essential factors, it is impossible to diagnose the cause of failures correctly. In spite of an investment of more than $3,000,000,000 in water distribution systems and the unquestionable importance of jointing materials, very little fundamental research has been reported on any of the materials or methods customarily used.

Because of a dearth of available fundamental information on so-called sulfur compounds, it has been impossible to diagnose correctly the difficulties associated with pipeline failures when sulfur jointing compounds have been used. As a service to water works engineers and in the interest of public health, the Executive Committee of the A.W.W.A., therefore, instituted an investigation in December 1946 to correct this deficiency. No fundamental research was initiated, however, for almost three years. As a result, A.W.W.A. specifications for the installation of cast-iron water mains were modified to include only lead and cement as jointing materials (1, 2).

This first research report represents only a small part of the investigation contemplated on this subject, but the data, presented with previously available practical information, should clarify problems of disintegration, stress and strain and corrosion of cast-iron pipe joints made with the sulfur compounds.

Because this work was undertaken as representative of the total fundamental research effort of all manufacturers of proprietary sulfur compounds, it was essential to consider two methods of attack: [1] an investigation of all proprietary compounds that still respected manufacturers' rights to special formulations, and [2] the development of a publishable formulation that would answer satisfactorily the questions previously raised.

The latter approach was considered to be of greatest service to water works engineers and, therefore, a formula was used that, in the light of fundamental research work completed to date, is not believed to contribute to disintegration, stress and strain, or corrosion of cast-iron pipe. This formulation, which meets Federal Specifications SS-C-608 for both hot- and cold-water

mains, will be referred to subsequently as the "Atlas" formula, and is given in Table 1.

Information obtained from this research program includes a brief history and a comparative report on various jointing materials and methods (3), the development of torsion testing equipment for cylindrical specimens (4), the physical properties of plasticized sulfur cements (5) and corrosion studies of iron in the presence of sulfur (6).

TABLE 1

Atlas Formula for Sulfur Compounds

Material	Proportion *per cent*
Sulfur	58.8
Graded silica aggregate	37.5
Phosphorus pentasulfide	0.1
Carbon	1.8
Thiokol	1.2
Sodium silicofluoride	0.6

Disintegration Problem

Sulfur-oxidizing bacteria are present in almost all soils but are more abundant in those rich in humus. Waksman (7) isolated *Thiobacillus thiooxidans,* which, according to Vogler (8), is simply an autotropic organism requiring sulfur or thiosulfate as specific materials, but, in their absence, can derive its energy from almost any organic compound containing sulfur. Similar or related organisms destroy concrete and Taylor (9) has therefore recommended the addition of bactericides to Portland cement used in underground structures, to prevent possible failures resulting from bacterial disintegration.

Almost 30 years ago, Bruce (10) presented evidence to show that, under proper conditions and in the absence of a bactericide, a proprietary mixture of sulfur, tar and oil used as a jointing material in earthenware pipe in Colombo tended to become oxidized to sulfate on the surface. Later Beckwith and Bovard (11) amplified this postulation in an attempt to explain the disintegration of joints in 20-in. cast-iron mains used to transport raw water from Natchez to Crockett, Calif. According to Frederick and Starkey (12), Beckwith's explanation suggests but does not explain the reason for the failure. The fact that a line joined with a proprietary non-bactericide-containing, plasticized sulfur compound has given good service for many years in the same locality would indicate that the disintegration could not be attributed to bacterial action.

In further studies, Beckwith (13, 14) noted the presence of *Thiobacillus thiooxidans* in water plant equipment and indicated that these bacteria could not be destroyed by chlorination. He suggested a cycle in which the sulfur was oxidized to sulfate in one zone, and, after reduction to sulfide, reacted with the iron in another zone. Such a process of course, could take place independently of sulfur jointing materials, but would not take place in sulfur joints containing a properly selected bactericide.

Duecker and coworkers (15) buried briquettes of sulfur compounds containing various bactericides in Newgulf, Tex., and Pittsburgh, Pa., and observed changes after five years. An examination of the products buried in Pittsburgh showed the tensile strength to be somewhat reduced, possibly due to freezing and thawing conditions, but there was no evidence of disintegration. Many of the samples at Newgulf, however, were attacked by bacteria, but such attack was retarded or prevented

by the presence of small amounts of B-naphthol or selenium.

Using more severe conditions that subjected the sulfur cement in a finely divided form to bacterial action, Frederick and Starkey (12) showed that the attack could be inhibited by at least fourteen different bactericides. These investigators emphasized, however, that in the absence of bactericides, finely divided jointing compounds were attacked much more slowly than sulfur, and that, since the attack rate was an inverse function of the particle size, any action on a solid joint would be exceedingly slow.

No reliable evidence has ever been presented to show bacterial attack on sulfur joints in water lines, but, to remove all possibility of such attack, sodium silicofluoride has been added for approximately five years by at least one manufacturer or proprietary sulfur compounds. The Atlas formula also contains 0.6 per cent sodium silicofluoride.

The disintegration of sulfur compounds may also result from the presence of soluble salts in the formulation. All soluble salt-containing sulfur-compound joints do not disintegrate, although soluble salts in sulfur can be leached out and thereby contribute to disintegration. Mock (16) has used this action to produce an insulator by leaching out soluble salts from a mixture of sulfur and sodium chloride. Duecker and coworkers (15) have shown that sulfur cements containing 1 per cent copper sulfate spalled and crazed rapidly when buried in the ground.

In another experiment, cement made in accordance with the Atlas formula with and without an additional 2 per cent sodium chloride was cast between rings of 2- and 4-in. pipe and placed in a 3-ft. deep sewer pipe covered with boards and loose dirt for a period of twelve months. As shown in Fig. 1, the ring made in accordance with the Atlas formula was unchanged, whereas the other one containing the Atlas formula plus 2 per cent sodium chloride disintegrated badly.

Both types of disintegration, it may be concluded, can be prevented by the use of an appropriate bactericide and by the elimination of soluble salts in sulfur-compound formulas.

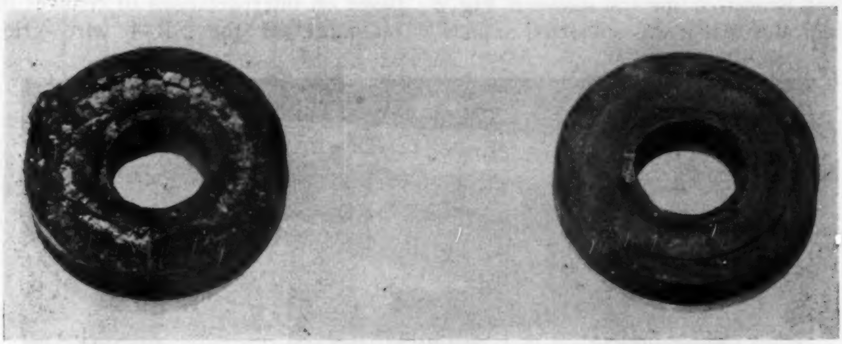

Fig. 1. Underground Disintegration With NaCl in Atlas Formula

Sulfur compound in left ring contained 2 per cent sodium chloride, whereas compound on right was salt-free.

Stress-Strain Problems

The prevention of the breaking of cast-iron water mains is one of the objectives of water works engineers, and obviously no jointing material that is responsible for the breakage of standard cast-iron pipe should be used. The occurrence of breakages at San Francisco, Calif., (17) and Wichita, Kan., is well known. These failures occurred approximately twenty and ten years ago, respectively, and unfortunately no reliable data are available for study. The pipe removed from the San Francisco line and shown in Fig. 2 indicates that it was subjected to enormous strains, as it split from the spigot end to within 6 in. of the bell.

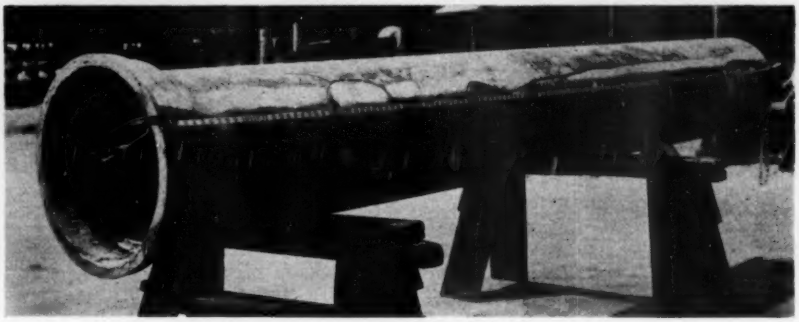

Fig. 2. Split Pipe From San Francisco Line

The split has progressed from the spigot end to within 6 in. of the bell.

Two previous studies are known to have been made using SR–4 strain gages, but descriptions of the exact techniques used have not been published. Strains of approximately 10,000 psi. have been reported, and statements have been made that sulfur joints can lead to an increased danger of bell cracking. The correctness of any conclusion depends largely on the reliability of techniques that are available when the investigation is undertaken. In fairness to previous investigators, it should be emphasized that, for almost two years, the combined efforts of six technologists and two technicians were directed toward the development of satisfactory techniques for the testing of pipe joints by the electrical strain-gage method.

The fundamentals of this technique have been described by Gibbons (18). Techniques and improved methods for determining strains under water (19, 20) have also been published. It should be observed that all strain measurements in these new techniques are based on interpretations of changes in resistance of the SR–4 wire grid. These changes can result from lengthening or shortening of the wire grid but may also result from temperature or humidity changes, so-called indicator drift, insulation breakdown, battery discharge, movement of leads, creep of bonding cements and other such factors. Unless proper precautions are taken, changes in resistance from uncontrolled variables may be interpreted as strains of extremely high magnitudes. Before any measurement can be interpreted correctly, the physical properties of the sulfur compound itself must be determined (5). More

than 1,000 physical tests were required to secure this preliminary information. As no method has been described previously to measure torsion, special equipment was developed (4). Other tests involve modifications of published methods (21). The preliminary work on physical tests indicated that stress-strain curves for a plasticized sulfur compound can be influenced considerably by the loading rate, as this material exhibits creep under load, although almost full recovery takes place after a sufficient lapse of time.

In the first stress-strain tests, plasticized sulfur cement was poured between two concentric iron rings. A series of stress-strain tests using conventional waterproofed, paper-mounted SR-4 gages was found, after intensive investigation, to give faulty results. A relatively new SR-4 gage, in which the wire grid is molded in a phenolic plastic, was therefore substituted for the simpler type gage. Although the new plastic SR-4 gage ordinarily requires a highly complicated mounting technique, it was employed because of the much more accurate readings it provides. Improvements in testing methods added further to the validity of the results, and, as shown in Fig. 3, no significant strain reading was noted with the bakelite gages after almost one month of immersion.

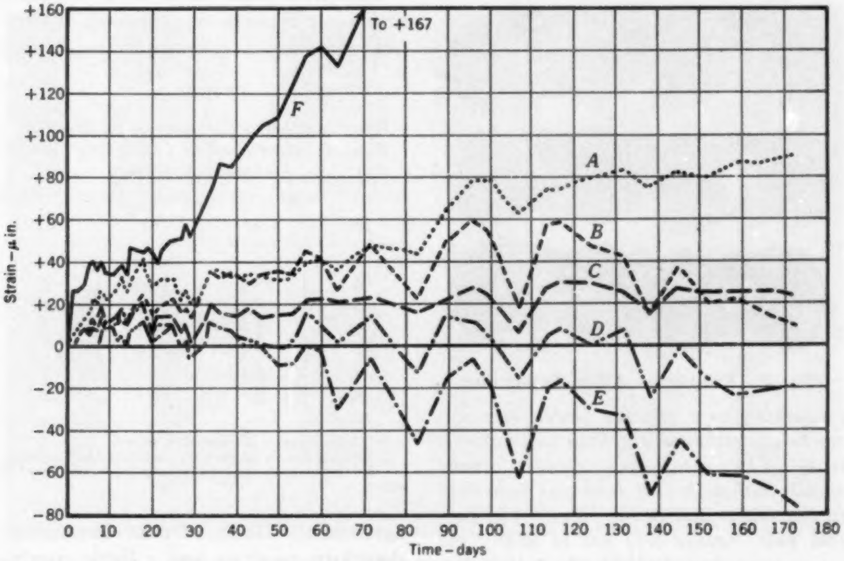

Fig. 3. Effect of Time on Strain Readings for Immersed Rings Jointed With Sulfur Compound

Bakelite SR-4 strain gages mounted on immersed iron rings give stress-strain readings. Curves A, C *and* F *show readings for circumferential outside;* B, D *and* E *for circumferential inside rings; Curve* F *shows reading with conventional SR-4 gage.*

Stagnant-water conditions used were much more critical than those ordinarily anticipated in actual service. The development of techniques for determining stress of joints immersed in

water are considered beyond the realm of this paper. In spite of previous reports, however, it may be concluded that under the conditions of test consisting of a one-month immersion period, sulfur joints made in accordance with the Atlas formula, even when immersed in stagnant water, do not contribute to strain in cast-iron pipe.

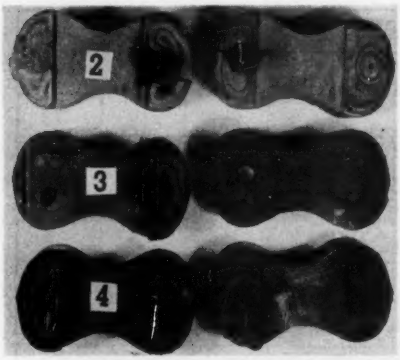

Fig. 4. Briquettes After Immersion

Immersion was effected under identical conditions although cracking was not uniform. The top pair cracked almost equally although cast iron was imbedded in one and a nail in the other. The bottom pair cracked less but to nearly the same degree within the pair.

Corrosion Problems

Corrosion of cast-iron pipe itself is a much more complicated problem than that of disintegration and strain and may never be solved, as it is difficult to differentiate between corrosion caused by stress or localized cells and that attributed to the jointing material. Many years of intensive investigation of corrosion by the National Bureau of Standards disclosed the fact that corrosion of cast-iron pipe itself is not only a function of the type of soil but also depends upon chemical composition and the method of pipe manufacture (*22*). Since the comparative results for corrosion, measured in mils of penetration, varied so widely among pit-cast, sand-cast and deLavaud pipe with various soils, the National Bureau of Standards has concluded that the thickness of the pipe wall has a greater effect on the pipe life than does the composition of the pipe itself.

Cast-iron pipe itself is a variable, and many reports on corrosion of various samples of cast iron are in disagreement. It is almost impossible, therefore, to draw any reliable conclusions on the corrosion of pipe in the presence of any other material. This factor has not deterred research efforts on corrosion, and, although the data may not be considered conclusive, they are at least as significant as any other information in this field.

TABLE 2

Effect of pH and Composition on Cracking Time of Sulfur Cements Containing Partly Embedded Iron Rods

pH	A*	B†	C‡
		months	
4	18+	18+	2
5	18+	18+	2
6	18+	18+	2
7	18+	18+	2
8	18+	18+	2
9	4	18+	2

* Atlas formula immersed in water.
† Atlas formula immersed in saturated salt solution.
‡ Atlas formula with 2 per cent NaCl, immersed in water.

In one recent investigation (6), the relative corrosion of cast iron by sulfur in the presence and absence of additives was determined by partially embedding an iron rod in a figure-eight sulfur-compound briquette. The entire unit was immersed in water under various conditions of pH, and the time

required for the briquette to crack was determined. An iron nail completely embedded in an Atlas-formula briquette was not affected after more than two years of immersion in solutions varying in pH from 4 to 9 in both the presence and absence of common salt. It is not suggested that either a completely embedded or partially exposed iron rod in a figure-eight briquette represents the actual conditions existing in a bell-and-spigot pipe joint, but practical conditions undoubtedly vary between these two extremes.

Iron nails rather than cast-iron pieces were used in most tests, since results obtained with either type of iron were sufficiently similar to justify this simplification. The two types of specimens before and after test are shown in Fig. 4. The final results are outlined in Table 2 and are shown in Fig. 5.

In briquettes in which iron pieces were completely embedded in sulfur cements made in accordance with the Atlas formula, no cracking or chemical attack was evidenced after two years. As shown in Table 2, however, partially embedded iron rods caused the briquettes to crack under some conditions. There was no cracking of briquettes containing partly embedded iron rods, even when immersed in saturated sodium chloride solutions for more than eighteen months at pH values of 4 to 8. High pH values, or the presence of soluble salts or of finely divided metals in a sulfur compound increased the tendency to crack.

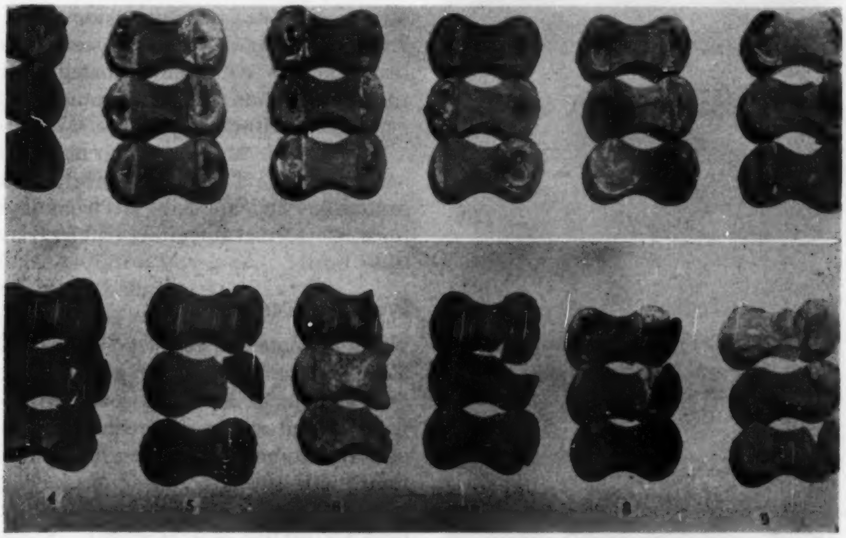

Fig. 5. Effects of Various pH Values and of NaCl

The top group shows the effect on briquettes of immersion at various pH values for eighteen months. Briquettes immersed in water with pH 9 cracked after four months. The bottom group shows the results of two months of immersion on briquettes made of the Atlas formula with 2 per cent sodium chloride.

In a related investigation, iron rods, both uncoated and protected with a proprietary coating, were partially immersed in sulfur compounds of the Atlas formula and of a similar composition to which 2 per cent sodium chloride had been added. All samples were immersed in water with a pH value of 9 and were removed after 40 days of exposure. The products of corrosion were collected in Petri dishes, as shown in Fig. 6. A proprietary plasticized sulfur cement without primer also produced essentially no deposit after 40 days of immersion. The iron rod itself, it should be noted, would deposit a considerable amount of rust after 40 days' immersion at pH 9, and this deposit would be similar to that obtained with the uncoated iron rods partly immersed in a proprietary, plasticized sulfur compound.

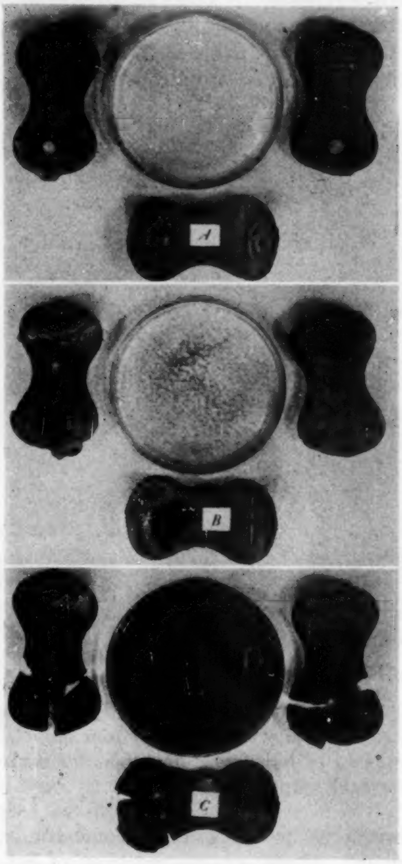

Fig. 6. Effect of 40 Days of Immersion at pH 9

Group A *shows corrosion products and condition of briquettes in which were imbedded coated iron nails. Group* B *shows results when uncoated iron nails were used. Group* C *shows the results of the addition of 2 per cent sodium chloride to the Atlas formula.*

Many accelerated corrosion tests are being made. These tests are based primarily on applied electromotive force, elevated temperatures and variations in pH.

Practical Tests

To simulate the worst possible conditions that might occur in a pipe joint, 5-ft. sections of 2-in. cast-iron soil pipe were capped with a piece simulating a bell and joined under various conditions with sulfur compositions. The pipe was filled with tap water, and the time for sealing was recorded. Some of the joints were exposed to air; others were buried in soil under various conditions.

After eighteen months, during which the pipes were kept filled with water, the joints were sawed vertically and examined. The cross-sections of these joints show no unusual corrosion whether or not rubber rings were used or whether the Atlas formula was used as such or with the addition of 2 per cent sodium chloride or 5 per cent iron filings (Fig. 7).

Particular attention should be paid to the contrast between the joint with rubber and the one with jute. With

the exception of the composition containing iron filings, all jointing materials examined after eighteen months were nonconductive, as they had been initially. All of the jute-packed joints, however, conducted an electrical current. Further evidence of the advantage of rubber rings is shown in Fig. 8, a photograph of actual lead joints poured with jute and with rubber rings.

Considerable corrosion occurred on the outside of the pipe when the joint was immersed in soil at a pH of 8 containing sodium chloride. This corrosion was not any greater at the sulfur-iron interface, however, than on the rest of the exposed pipe. Eighteen months is too short a time to allow for valid conclusions, but longer periods for tests of this type were unobtainable. Since, with stagnant water, the conditions of test were essentially anaerobic, test conditions were at least as severe as those that might be expected in an ordinary distribution system.

In additional short-term tests, using jute as a packing, four joints were poured in a 12-in. cast-iron pipeline. These joints were composed of: [1] the Atlas formula, [2] a proprietary plasticized sulfur cement, [3] the proprietary plasticized sulfur cement using pipe primed with a proprietary system and [4] cement made in accordance with the Atlas formula on a pipe primed with the proprietary system.

The takeup rate under pressure with all joints except No. 3, above, was similar. The proprietary priming system did not interfere with the sealing in any way, and yet it should somewhat protect the adjacent areas from external corrosion. The takeup rate, in terms of gallons per inch of diameter per mile per 24 hours, on a specific job using 8–12-in. water lines is shown

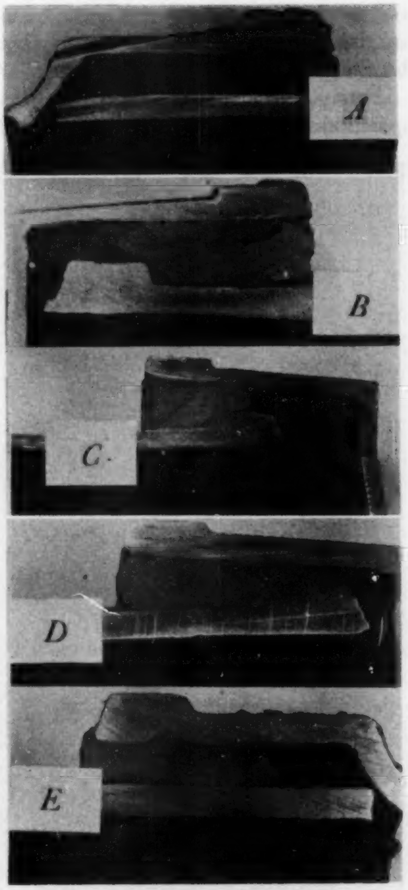

Fig. 7. Effects of Tap Water

All joints are shown after 18 months exposure to noncirculating tap water. Joint A *is a sulfur joint packed with jute and immersed in salt-containing soil with a pH of 9. Exterior showed fairly uniform corrosion. Joint* B *was made from Atlas formula containing 2 per cent sodium chloride. Marks in the compound are from extraction of soluble salts. Joint* C *is a sulfur joint with rubber ring. No corrosion is shown in contact with the sulfur compound. Joint* D *is a sulfur cement joint made from Atlas formula with 5 per cent iron filings. Joint* E *is a sulfur joint using primed spigot and bell.*

in Fig. 9. Here as elsewhere, the take-up time would be reduced considerably by the use of rubber rings.

From a study of 268 replies to a questionnaire circulated in June 1949 among 771 known users of sulfur jointing compounds, it was concluded that less difficulty was experienced with all types of jointing materials and methods than had been anticipated. Although the questionnaire was sent only to known users of sulfur jointing materials, the frequency of breaks reported with both sulfur compounds and lead was essentially the same. Pitting was not a frequent complaint and appeared to occur as frequently with lead as with sulfur compounds.

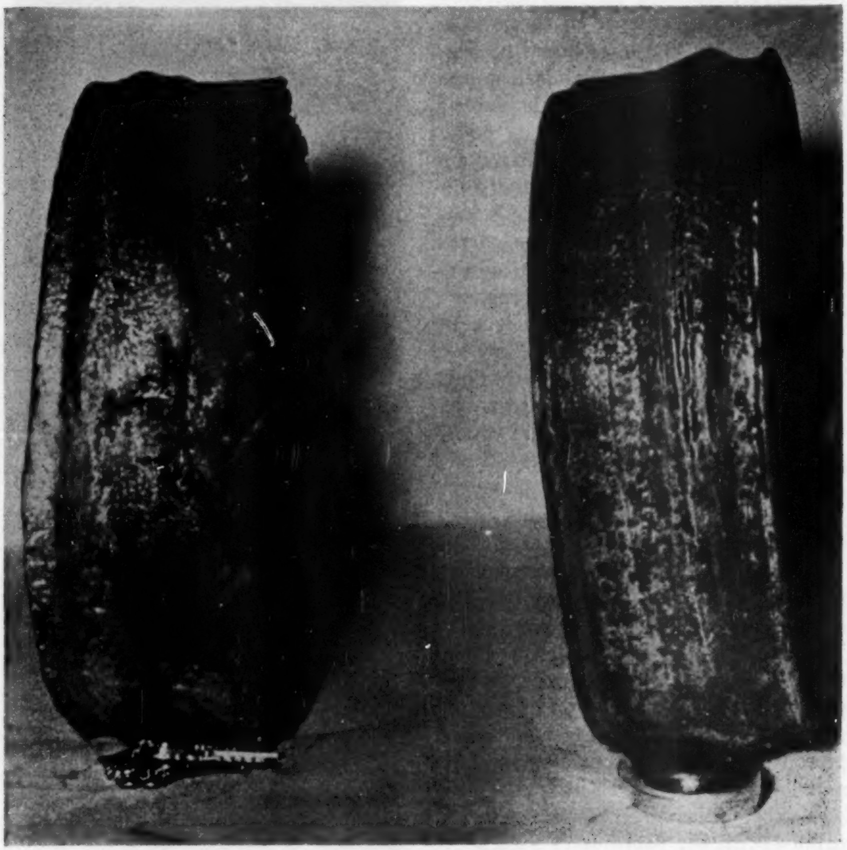

Fig. 8. Lead Joints

Shown is lead removed from joint in a 21-in. cast-iron main. Joint on right was cast with rubber ring and joint on left with jute.

Four complaints were also received describing breakage of bells with Portland cement joints, whereas no complaints were received of the disinte-

gration of Portland cement joints, although such troubles have been reported (23). A critical examination of other surveys, including reports of joints actually returned for laboratory test, will show that the trouble encountered with sulfur joints to date is statistically insignificant and certainly no greater than that encountered with other jointing methods and materials.

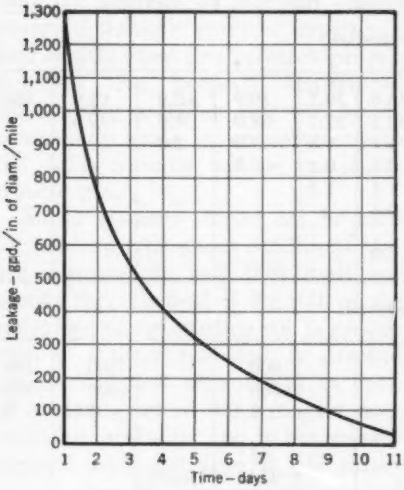

Fig. 9. Leakage Test

This leakage test was performed on an actual job. The takeup rate, in gallons per inches of diameter per mile per day, is given for 8–12-in. pipelines.

To draw conclusions of maximum practical value, larger-scale experiments under controlled conditions in actual pipelines will be required. It is expected, however, that the large-scale tests will merely verify all laboratory research conclusions.

Theory of Sealing

One advantage of sulfur-compound joints is that they are self-calking. It is difficult, however, to state exactly what occurs during the sealing period. According to one report (24), "the sulfur joints react with water pressure to elastically expand or adjust themselves sufficiently to cause closing of the voids without injury to the pipe." Independent observers have stated that some corrosion of the cast iron by the cement is necessary for proper performance of the cement. They have agreed, however, that the degree of corrosion for proper functioning is so small that no appreciable weakening of the cast-iron parts would result. Another explanation is that sulfur migrates, in the form of soluble sulfides, from the interior to the exterior, whereas iron migrates in the reverse direction.

Properly constructed joints containing no added salt or iron show no evidence of sulfur or iron migration, but they do show a thin, black line adjacent to the iron surfaces—presumably iron sulfide. This thin ring of iron sulfide is believed to progress throughout the joint and oxidize to iron oxide, which has a lower specific gravity. As iron rods completely immersed in sulfur cement that is made in accordance with the Atlas formula were unaffected after two years of immersion under conditions of varying pH, this premise would seemingly not apply to a compound of this composition. If iron and iron sulfide could migrate in rhythmic processes throughout the compound, smaller molecules such as water would probably migrate at least as well and would attack the protected iron rod. An initial reaction between the iron surface and sulfur in a properly constructed joint is indicated, but this action does not appear to continue unless the joint is broken and resealed.

Effect of Composition on Properties

Each constituent in the Atlas formula, as shown in Table 3, makes a specific contribution to the performance of the jointing material. Sulfur itself is required for the melting process, but it is known to have low tensile strength. The addition of silica increases the strength; the extent of this increase depends upon the use of properly graded silica aggregate. Finely divided carbon black aids in the suspension of the mix, although, when used in accordance with the amounts specified in the Atlas formula, it does not contribute to conductivity. Phosphorus pentasulfide produces a more fluid mix than sulfur itself and permits the compound to flow to all parts of the joint before solidification. Thiokol * produces ductility and decreases the coefficient of expansion considerably, thus minimizing the shrinkage and hastening sealing. Sodium silicofluo-

TABLE 3

Effect of Composition on Properties of Sulfur Compounds

Sulfur Compounds	1*	2	3	4	5	6	7	8
Chemical Properties								
Sulfur—%	58.8	57.7	56.0	59.2	59.9	60.0	61.0	100
Graded Silica—%	37.5	36.6	35.5	37.7	38.0	38.0	39.0	
Carbon—%	1.8	1.8	1.7	1.8	2.0	2.0		
Phosphorus Pentasulfide—%	0.1	0.1	0.1	0.1	0.1			
Thiokol—%	1.2	1.2	1.1	1.2				
Sodium Silicofluoride—%	0.6	0.6	0.6					
Sodium Chloride—%		2.0						
Iron—%			5.0					
Physical Properties								
Tensile Strength—*psi.*	600				600		400	180
Compression Strength—*psi.*	6000				6000		4000	1800
Elasticity (Deflection†)	0.25				0.17		0.05	0
Expansion Coefficient In. per °F. $\times 10^{-6}$	15				45			
Viscosity at Pouring Temp.	Thin				Thin	Heavy		
Settling Resistance	Good				Good		Poor	
Impact Resistance‡	7				1			
Temp. Shock Resistance	Excellent				Poor			
Bacteria Resistance	Excellent			Poor				
Resistance to Deterioration by Water	Excellent	Poor						
Cracking Resistance§	Excellent	Poor	Good					

* Atlas formula
† Deflection of a test bar 24 × 1 × ½ in.
‡ Number of times required to break a figure-eight briquette supported on bars 2 n. apart by dropping a ½-lb. weight 1 ft.
§ See Table 2 and related test methods.

* A product of The Thiokol Corp., Trenton, N.J.

ride (12) prevents attack by sulfur bacteria.

Conclusions

An attempt has been made to answer the questions raised on disintegration, stress and strain, and corrosion. Questions have also been asked about alleged failures of pipe joined with sulfur cement. Although these failures are considered statistically insignificant, an analysis of practical results observed through years of experience and of data from this research project indicates that properly constructed joints using a rubber ring and sulfur compounds made in accordance with the Atlas formula will be essentially trouble-free.

Sulfur cements should not be used in cast-iron pipe under conditions that are corrosive to cast iron itself nor should they be used if the pH of the water or the surrounding soil is greater than 9. Sulfur, like lead, is attacked by alkalies, and although it is completely resistant to the strongest nonoxidizing acids, its use is not recommended with cast iron at pH values of less than 4. Properly constructed sulfur joints may be used with confidence under all normal conditions, or for at least 90 per cent of all pipelines.

Acknowledgment

The authors express their appreciation to the Atlas Mineral Products Co. for supporting this investigation. The contributions of George L. Wirtz Sr., Carl DeLong, J. D. Fenstermacher, Arthur L. Moser and Donald F. Deakin are gratefully acknowledged.

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What Next in Securing Materials?

The National Production Authority, on November 29, notified domestic telephone, telegraph and cable operators that initial applications for authorized programs and allotments of controlled materials under Order M–77 for the second quarter of 1952 would have to be submitted by December 22, 1951. Its directive also provided that applications for subsequent quarters *must be filed at least 120 days before the beginning of the quarter.* Thus, for communications utilities, March 1, 1952, will be the deadline for applications covering the third quarter of the year—this advance filing date permitting NPA to return CMP allotments and program approvals earlier than previously and, in turn, enabling operating companies to place authorized materials orders within the lead times required by their suppliers.

Although the new directive now applies *only* to Order M–77, governing the procurement and use of materials for maintenance, repair and operating construction (MRO) by communications systems, it is, of course, quite possible that the same pattern will soon be applied to all orders and all industries. That, in itself, is not of major moment. But what is of first importance is the clear indication that the water industry cannot be dilatory in planning its programs, in estimating its materials needs and in submitting its applications and orders *if it is to accomplish its objectives!*

Protective Coatings Used on Gas Pipe

By Roy T. Richards and N. K. Senatoroff

A symposium presented on Mar. 30, 1951, at the Arizona Section Meeting, Grand Canyon, by Roy T. Richards, Gen. Supt., System Gas, Central Arizona Light & Power Co., Phoenix, Ariz., and N. K. Senatoroff, Chem. Engr., Southern Counties Gas Co. of California, Los Angeles.

Experience of the Central Arizona Light and Power Co.—*Roy T. Richards*

THE Central Arizona Light and Power Co. has used many different types of protective coatings during the past 45 years in its effort to find a satisfactory means of combating corrosion of its gas system piping.

From 1906 to 1911, tar produced in the manufacture of gas from crude oil was used to protect the pipe. Inspections have shown that this type of coating was generally satisfactory.

From 1911 to 1925, the pipe coating consisted of red lead painted on the surface. This type of treatment was not satisfactory. Numerous inspections of pipe ranging in age from 8 to 20 years revealed numerous and deep pits on all sections examined.

During the last five years of this period of red lead use, the pipe was laid in a ditch containing oil and sometimes oil-soaked backfill was used adjacent to the pipe. Inspections have shown that this variation of the treatment was satisfactory.

From 1925 to 1927, crude-oil–tar wrapped with burlap was used. Inspection records show that, although some pits were found, the protective coating was generally satisfactory.

From 1927 to 1930, asphalt wrapped with burlap was used. Inspections have shown that this type of treatment was not satisfactory.

Starting in 1930, paint with an asphalt base was used. This type of treatment was very poor. Inspections showed that numerous and deep pits occurred within two or three years of installation. Also from 1930 to 1932, cast iron with brazed joints was used with no protective coating and found very unsatisfactory. Graphitization occurred generally, and numerous breaks in the pipe resulted in the need for excessive maintenance.

Since 1932 coal tar wrapped with asbestos felt has been used as a protective treatment on all gas pipe installed. As experience with this type of covering has been very satisfactory, the company has required an application consisting of: primer; two layers of hot coal-tar enamel; one layer of 15-lb. coal-tar-saturated asbestos felt; one layer of hot coal-tar enamel; and, then, one layer of kraft paper.

Application Procedure

Very rigid specifications to cover the application of this protective coating have been established, as it is believed that extreme care must be used to obtain a successful coating for the pipe.

Proper preparation of the metal surfaces is the basic requirement, and, in order to ascertain that a proper metal surface is obtained, a "Wheelabrator" * is specified for the cleaning process. This machine consists of a device that hurls steel grit upon the pipe and thereby effectively removes rust, dirt and mill scale, and etches the surface into many tiny facets inclined toward each other at various angles. This etching provides a surface which helps to key or bond the coating to the steel. Considering the efficiency of a surface cleaned with a "Wheelabrator" as 100 per cent, sand blasting is rated from 70 to 80 per cent, whereas wire brushing is only 40 to 50 per cent effective.

Great care is required to obtain proper application of the primer, as the successful bonding of the enamel to the pipe depends on: first, the use of the correct primer for the enamel to be used; and, second, the proper application of the primer. The primer should be dry before the enamel is applied. The enamel will not bond satisfactorily if the primer is wet or if the primer is allowed to dry too long.

The coal-tar enamel is applied under the conditions recommended by its manufacturer. Great diligence is given to the care, cutting, heating and agitation and holding the application temperature of the enamel at the correct value.

The coal-tar-saturated asbestos felt is applied at the same time as the enamel in order to provide a perfect bond. This bonded wrapper gives reinforcing strength to the enamel and is of great benefit in overcoming soil stress. It also serves as a protection from pressure caused by stones and other objects in the backfill that tend to puncture the coating.

The coated pipe is handled with great care from the time it leaves the wrapping machine until it is covered in the trench. Field joints are protected with the same materials as used on the pipe. The pipe joint is thoroughly wire brushed after welding to remove all dirt and welding slag, and the edge of the wrapping material at each end of the joint is beveled to provide a good surface for the bonding of the joint covering with the pipe covering.

Other Methods

Approximately a year ago, the company commenced use of cathodic protection on its gas pipelines to supplement the protection given by the coal-tar protective coating. This process is used on sections of the distribution system that show excessive corrosion. Systematic soil analyses and pipeline inspection are being made to make possible a determination of the locations where and the amount of cathodic protection that is needed.

Future research will undoubtedly develop improved techniques of protection in combating corrosion, but too great emphasis cannot be given to the importance of using present knowledge of protective measures to decrease the tremendous and needless waste of corrosion now.

* A product of American Wheelabrator & Equipment Corp., Mishawaka, Ind.

Experience of the Southern Counties Gas Co. of California—*N. K. Senatoroff*

THE customary practice of selecting the coating quality in the Southern Counties Gas Co. of California is based on the "corrosivity" of the soil which is traversed by the right of way of the pipeline or by the network of the gas distribution system. Soils within the geographical boundary of the operating division of the company are divided into four color classes according to their electrical resistivity and, in turn, to their relative corrosivity:

Color	Resistivity *ohm-cm.*	Corrosivity
Red	0–749	Extremely corrosive
Brown	750–2,599	Corrosive
Blue	2,600–9,999	Moderately corrosive
Green	10,000 and more	Noncorrosive

Soil Tests and Maps

Soil resistivity tests are made with an earth resistivity meter (soil rods). Several readings are taken in each set of two holes and only the lowest resistivity reading is recorded. All such tests are made in wet holes. The holes are made with a 1-in. steel drill or a bar, and into the bottom of each is poured 2 oz. of water to provide better contact between the tips of the rods and the moist soil. The intervals between the test points along the proposed route are varied between 25 and 500 ft. depending upon the uniformity of the soil resistivity readings.

The location of each soil test taken is shown on the map attached to the application for construction order and subsequently entered on the division working soil map.

A set of 600-ft. scale blue-line-on-linen maps is maintained in each division. Colorings show the areas in which the four classes of soils are distributed. The boundaries of the colored areas on these maps are periodically reviewed and revised as additional soil-rod readings or corrosion experience may indicate.

Coating Specifications

The coatings as listed in Table 1 are numbered solely to facilitate clerical work and have a special meaning only within the company. The No. 7 coating, standard or modified, is used chiefly on large diameter gas mains, from 2 in. up, and the No. 9 coating, standard or modified, is used almost exclusively on the so-called service pipe ranging from $\frac{3}{4}$ to 2 in. id. Both No. 7 and 9 coatings are applied in the company yard, generally by the use of special pipe-coating machines.

The two types of coatings are made up of primer, a layer of coal-tar enamel and reinforcing shield in the form of a wrap, which is intended to supplement the dielectric properties of the enamel with mechanical reinforcement in the form of glass or asbestos-felt wrapper. The protective properties of the materials constituting the coatings are serving their purpose and justify their cost if they are carefully applied and are acting, although laminated, as one reinforced dielectric and continuous covering for the pipe. The detailed specification of the methods of application shown in Table 1 is the company's own procedure. This procedure, it is felt, achieves the economically best protective results for underground pipes.

TABLE 1

Coal-Tar Enamel Coatings Used

Coating No. 7, Standard:

A. One coat of coal-tar primer.

B. One or two coats of coal-tar enamel, $\frac{3}{32}$ in. minimum thickness.

C. One wrap of coal-tar-impregnated 13-lb. asbestos felt.

Application: By yard machine.

Coating No. 7, Modified (used in special installations on large diameter pipe):

A. One coat of coal-tar primer.

B. One or two coats of coal-tar enamel, $\frac{3}{32}$ in. minimum thickness.

C. One wrap of glass felt.*

D. One coat of coal-tar enamel, $\frac{1}{32}$ in. minimum thickness.

E. One wrap of kraft paper.

Application: By yard machine.

No. 7 Field Joints:

A. One coat of coal-tar primer.

B. One or two coats of coal-tar enamel, $\frac{3}{32}$ in. minimum thickness.

C. One wrap of glass felt* (not allowed to lap over yard-applied coating).

D. One or two coats of coal-tar enamel, $\frac{1}{32}$ in. minimum thickness (extended 4 or 5 in. over the yard-applied coating on each side of the joint).

E. One wrap of coal-tar-impregnated 13-lb. asbestos felt (extended over full length of the last coat of enamel).

Application: By hand in the field.

Coating No. 9, Standard:

A. One coat of coal-tar primer.

B. One or two coats of coal-tar enamel, $\frac{3}{32}$-in. minimum thickness.

C. One wrap of coal-tar-impregnated 13-lb. asbestos felt.

D. One coat of coal-tar enamel, $\frac{2}{32}$-in. minimum thickness.

E. One wrap of coal-tar-impregnated 13-lb. asbestos felt.

Application: By yard machine.

Coating No. 9, Modified (used in special circumstances on large diameter pipe):

A. One coat of coal-tar primer.

B. One or two coats of coal-tar enamel, $\frac{3}{32}$-in. minimum thickness.

C. One wrap of glass felt.*

D. One coat of coal-tar enamel, $\frac{2}{32}$ in. minimum thickness.

E. One wrap of coal-tar-impregnated 13-lb. asbestos felt.

Application: By yard machine.

No. 9 Field Joints:

A. One coat of coal-tar primer.

B. One or two coats of coal-tar enamel, $\frac{3}{32}$ in. minimum thickness.

C. One wrap of glass felt* (not allowed to lap over yard-applied coating).

D. One coat of coal-tar enamel, $\frac{2}{32}$ in. minimum thickness (extended 4 or 5 in. over the yard-applied coating on each side of the joint).

E. One wrap of coal-tar-impregnated 13-lb. asbestos felt (extended over full length of the last coat of enamel).

Application: By hand in the field.

Primer:

Primer used on the job shall be coal-tar primer as received in original containers. No thinner or other material shall be applied to the primer.

Enamel†*:*

All coal-tar enamel used on the job shall be coal-tar pipeline or millwrap enamel having the following physical properties:

A.	Melting point (ring and ball), °F.	170–203
B.	Average weight per cubic foot, *lb.*	86– 91
C.	Application temperature, °F.	365–380
D.	Maximum allowable temperature to which enamel may be heated, °F.	425
E.	Maximum time enamel may be held in heating kettle at application temperature, *hours*	1½

* Not designated in A.W.W.A. specifications. The product to which the author refers is "Fiberglas," manufactured by Owens-Corning Fiberglas Corp., Toledo, Ohio.—*Ed.*

† See specifications A.W.W.A. C203–51 and C204–51 (formerly 7A.5 and 7A.6).

Pipe and Coatings for Various Soils

To be effective, the pipe coatings selected to comply with stated specifications must be properly applied and, subsequently, properly handled to prevent damage that might destroy their protective quality.

Inspection is maintained during all pipe-coating applications performed in the company yard or in the field by the contractor, to insure the standard of quality of the wrapping job. After wrapped pipe is shipped, it is inspected for damage in transit, and a full report is submitted to the manager of purchasing and stores whenever damaged or improperly handled coatings are discovered.

The type of protective coating to be used in each soil class is given in Table 2.

When more than one color class of soil is found along the route of a proposed new main, a protective coating specification complies with the requirement imposed by the most corrosive soil encountered on the right of way. If a continuous stretch 300 ft. or more in length of less corrosive soil is traversed, however, the coating used in the more corrosive area is normally extended only 50 ft. from each end of the boundary line into the less corrosive soil and the less vigorous requirement followed for the balance of the less corrosive stretch.

On mains to be placed under cathodic protection, a continuous length of No. 7 coated pipe is normally used. All buried metal surfaces which come in contact with this pipe, including such items as gear-operated valves, casings over valves and pipe crossings, are also coated to comply with specification No. 7.

Soil resistivity tests are omitted on service installations because all steel services are coated with No. 9 coating, regardless of soil class.

TABLE 2

Coatings Used for Different Soil Conditions

Type of Pipe	Coating Used for:		
	"Red" Type Soil	"Brown" or "Blue" Type Soil	"Green" Type Soil
Steel services	9	9	9
Steel mains smaller than 6-in. diameter	9	7	15*
Steel mains 6 in. or larger in diameter:			
When cathodically protected	7	7	7
Not cathodically protected	9	7	15

* Primer only.

Coating Quality Testing

As the principal characteristic of enamel coating is its high dielectric property, it is mandatory that all faults in the coating which tend to decrease the continuity of its dielectric property be eliminated or repaired before the backfilling of the coated pipe. Because some of the coating defects are impossible to detect by visual inspection, it has become standard practice to inspect their quality by means of a "holiday" detector. Such a detector is an electrical device providing a potential of

9,000–12,000 volts at the exploring surface of the electrode, which is discharged in the form of an electric spark at the encountered "holiday" in the coating.

Accurate records of repairs to pipe wrapped with coal-tar enamel and asbestos have been kept for the past fifteen years. In spite of the quality of workmanship and materials available at the beginning of that time, the records indicate indeterminate service life. Current testing methods, such as bond strength and high-potential detector tests, applied to coatings which have served under actual pipeline operation conditions for more than fifteen years, give no indication of coating deterioration.

Workmanship

The necessity for careful, thorough workmanship from start to finish in cleaning, coating and inspecting the pipe surface before the coating is applied and the importance of inspection of the integrated coating surfaces while in the process of building up a coating should be emphasized again and again. In providing the essential features of a coating procedure that consistently results in good corrosion protective qualities of the coating, it is just as important to provide for a clean pipe surface prior to priming as it is to specify a clean primed pipe surface before enameling. The men engaged in pipe coating and pipe protection work —especially the foremen—should be given adequate instructions on the purpose of the coating and the details of the methods used in applying it. The foreman should be impressed with the enormous losses that can result from soil corrosion if he fails to see that the work is done properly.

Coating Costs

The cost of applying coating varies with the diameter of the pipe. The cost per foot, in cents, including labor, material and all direct expenses, is approximately four to five times the diameter of the pipe in inches. Labor and material each roughly constitute $1\frac{1}{2}$ to 2 times the diameter. This cost per foot ratio, however, varies depending upon the diameter, gradually decreasing with the increase in pipe diameter.

AWWA
B501-51T

American Water Works Association

Tentative

STANDARD SPECIFICATIONS

for

CAUSTIC SODA

These "Tentative Standard Specifications for Caustic Soda" are based upon the best known experience and are intended for use under normal conditions. They are not designed for use under all conditions and the advisability of use of the material herein specified in any water treatment plant must be subjected to review by the chemist/engineer responsible for operations in the locality concerned.

Approved as Tentative by the Board of Directors of the A.W.W.A. on Oct. 15, 1951

First Printing, December 1951

AMERICAN WATER WORKS ASSOCIATION
Incorporated
521 Fifth Avenue, New York 17, N.Y.

Table of Contents

These "Tentative Standard Specifications for Caustic Soda" were prepared under the direction of C. K. Calvert (deceased) and J. E. Kerslake of the Water Purification Division, A.W.W.A. The specifications were approved by the Executive Committee of the Water Purification Division and by the Water Works Practice Committee, and received the approval of the Association's Board of Directors on July 1, 1949. The specifications were also submitted for review to producers and consumers of the materials involved, whose comments were then considered by M. D. Baker, acting as referee. The text as finally edited was approved by the Executive Committee of the Water Purification Division on February 12, 1951, and was reaffirmed by the Board of Directors on October 15, 1951.

Tentative
Standard Specifications for Caustic Soda

Part A—Material Specifications

Sec. 1A—Scope

These specifications cover caustic soda, solid or liquid, for use in the purification of municipal and industrial water supplies. The specifications are intended for use with Part B (Sampling, Inspection, Packing and Marking) and Part C (Testing Methods) of this document.

Sec. 2A—Definition

Caustic soda is a compound produced in [1] the electrolytic manufacture of chlorine or [2] the causticizing of soda ash with lime. In the solid form, it is a white, opaque or translucent, very deliquescent solid which rapidly absorbs moisture from the atmosphere.

Sec. 3A—Sampling

Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing and Marking) of this document.

Sec. 4A—Methods of Testing

The laboratory examination shall be carried on in accordance with Part C (Testing Methods) of this document.

Sec. 5A—Impurities

The caustic soda shall not contain any compound that will produce a toxic effect upon the consumer of a properly treated water.

Sec. 6A—Rejection

6A.1. Notice of dissatisfaction with a shipment, based on the specifications, must be in the hands of the consignor within ten days after receipt of the shipment at the point of destination. If the consignor desires a retest, he must notify the consignee within five days of the notice of complaint. Upon receipt of the request for a retest, the consignee shall forward to the consignor one of the sealed samples. In the event that the results obtained by the consignor, on retesting, do not agree with the results obtained by the consignee, the other sealed sample shall be forwarded, unopened, for analysis to a laboratory agreed upon by both parties. The results of the referee shall be accepted as final and the cost of the referee's analysis shall be paid for by the party whose results show the greatest departure from the referee's results.

6.A.2. On the basis of the retest or the referee test, the consignor may remove the material from the premises of the consignee, or a price adjustment may be agreed upon by the consignor and consignee.

Sec. 7A—Total Alkali (Na_2O)

7A.1. Solid caustic soda shall contain a minimum of 75.5 per cent total alkalinity as Na_2O, 96 per cent sodium hydroxide as NaOH and not more than 2 per cent carbonate as Na_2CO_3.

7A.2. Liquid caustic soda shall contain approximately 50 per cent sodium hydroxide (NaOH). Liquid caustic soda containing approximately 73 per cent NaOH is also available.

Any strength of solution shall be sold on the basis of 75.5 per cent Na_2O as determined by the following formula:

$$\frac{\text{Weight of shipment} \times \text{per cent } Na_2O \text{ as determined}}{75.5} = \text{equivalent weight 75.5 per cent } Na_2O \text{ in caustic soda.}$$

Part B—Sampling, Inspection, Packing and Marking

Sec. 1B—Scope

These procedures for the sampling, inspection, packing, weighing and marking of caustic soda are intended for use with Part A (Material Specifications) and Part C (Testing Methods) of this document.

Sec. 2B—Sampling

2B.1. Samples shall be taken at the point of destination.

2B.2. Five per cent of the packages shall be sampled; no sample shall be taken from a broken package.

2B.2.1. Unground caustic soda shall be sampled by breaking off small pieces from the top, bottom, and sides of the package at numerous locations. Sample particles shall be small enough to use for analysis without further crushing.

2B.2.2. Ground or flake caustic soda may be sampled by means of a sampling tube which is at least ¾ in. in diameter.

2B.2.3. Packages of caustic soda in solution shall be mixed thoroughly by rolling or other means and sampled properly, preferably by tube. Samples from tank cars can be obtained by means of a "thief" sampler.

2B.2.4. Sampling of solid caustic soda must be carried on quickly, preferably on days when the atmosphere is not unusually damp, and sealed as quickly as possible to avoid absorption of moisture and carbon dioxide from the air.

2B.3. The gross sample, weighing at least 10 lb., shall be crushed * if necessary, mixed thoroughly, and carefully divided to provide three 1-lb. samples. These shall be sealed in air-tight, moisture-proof, glass containers. Each sample container shall be labeled to identify it and shall be signed by the sampler.

2B.4. When sampling caustic soda in solution, the gross liquid sample (approximately 1 gal.) shall be thoroghly mixed and approximately 1 pint of the mixed solution shall be placed in each of three air-tight, moisture-proof sealed glass or steel containers. Each sample container shall be labeled to identify it and shall be signed by the sampler.

Sec. 3B—Packing and Shipping

3B.1. Unground caustic soda is customarily shipped in steel drums containing 700–725 lb. net weight Flake or ground caustic soda is shipped in steel drums, kegs, barrels or heavy cardboard drums ranging from 50 to 500 lb. net weight.

3B.2. Liquid caustic soda is shipped in carboys, in 50–55 gal. steel drums or in tank cars.

* It has been recommended that unground caustic soda be crushed to sampling size by first folding it in Canton flannel both to protect the worker and to reduce contact with the atmosphere.

3B.3. The net weight of packages shall not deviate from the recorded weight, plus or minus, by more than 1.5 per cent. If exception is taken to the weight of the material received, it shall be based on the certified unit weight of not less than 10 per cent of the packages shipped, selected at random from the shipment.

Sec. 4B—Marking

Each shipment of material shall carry with it some means of identification. Each package shall be marked with the net weight of the contents, the name of the manufacturer, and the brand name, if any. The package may also bear the statement "Guaranteed by (name of manufacturer) to meet the specifications of the American Water Works Association for caustic soda."

Sec. 5B—Caution

Great care should be exercised in handling caustic soda both in liquid and solid form. Handlers should be given detailed instructions on how to avoid injury, and proper protective clothing, including goggles or face shields, should be provided. Containers used in shipping should comply with the specifications for containers of the Interstate Commerce Commission.

Part C—Testing Methods

Sec. 1C—Scope

These methods for the examination of caustic soda are intended for use with Part A (Material Specifications) and Part B (Sampling, Inspection, Packing and Marking) of this document.

Sec. 2C—Sampling

2C.1. Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing and Marking) of this document.

2C.2. Solid caustic soda is very deliquescent, and, to avoid moisture absorption, must be mixed thoroughly and sampled as rapidly as possible. The sample should be stored in an air-tight glass container and any weighing of a sample should be done as rapidly as possible to avoid change in moisture content.

2C.3. Portions allotted for the examination of solutions of caustic soda may be removed from the sample delivered to the laboratory; care must be taken not to expose the solution to the atmosphere any more than is necessary, to avoid the absorption of carbon dioxide.

2C.4. Laboratory examination of the sample shall be completed within five working days after receipt of the shipment.

Sec. 3C—Total Alkali as Na_2O

3C.1. *Reagents:*

3C.1.1. 1.0*N* hydrochloric acid.

3C.1.2. Methyl orange indicator.

3C.2. *Procedure:*

3C.2.1. *Caution.* When solid caustic soda is added to water, there is a violent evolution of heat. Care should be taken to add ample water to the soda to reduce the intensity of the reaction and therefore of the heat produced.

3C.2.2. Transfer approximately 12 g. from the sample bottle into a tared weighing bottle. Weigh this sample accurately.

3C.2.3. Transfer the weighed sample to a 1,000-ml. volumetric flask and rinse the weighing bottle into the flask

with freshly boiled and cooled distilled water. After the caustic soda is dissolved, cool it to tap water temperature and allow to stand until room temperature is reached. Fill the flask completely with freshly boiled and cooled distilled water and mix thoroughly.

3C.2.4. Titrate 100 ml. from the 1,000-ml. flask with 1.0*N* hydrochloric acid (HCl), using methyl orange indicator.

3C.2.5. *Calculation:*

$$\frac{\text{Ml. } 1.0N \text{ HCl} \times 10 \times 0.031}{\text{Weight of sample}} \times 100 = \text{per cent total alkali } (Na_2O)$$

Sec. 4C—Total Hydroxide

4C.1. *Reagents:*

4C.1.1. 1.0*N* hydrochloric acid.

4C.1.2. 10 per cent solution barium chloride.

4C.1.3. Phenolphthalein indicator.

4C.2. *Procedure.*

4C.2.1. The solution prepared as directed in Sec. 3C.2.3 shall also be used for the determination of total hydroxide.

4C.2.4. Place 100 ml. of solution from the 1,000-ml. flask into a beaker. Add 5 ml. of 10 per cent barium chloride solution, swirl to mix thoroughly; add phenolphthalein indicator, and titrate to the neutral point, using 1.0*N* hydrochloric acid. Record the burette reading.

4C.2.5. *Calculation:*

$$\frac{\text{Ml. } 1.0N \text{ HCl} \times 10 \times 0.031}{\text{Weight of Sample}} \times 100 = \text{per cent of NaOH as } Na_2O$$

$$\frac{\text{Ml. } 1.0N \text{ HCl} \times 10 \times 0.040}{\text{Weight of Sample}} \times 100 = \text{per cent of NaOH}$$

Sec. 5C—Sodium Carbonate

5C.1. *Reagents:*

5C.1.1. 1.0*N* hydrochloric acid.

5C.1.2. Phenolphthalein indicator.

5C.2. *Procedure:*

5C.2.1. Place 100 ml. of the sample (4C.2.4) in a beaker; add phenolphthalein indicator and titrate with 1.0*N* hydrochloric acid. Record the burette reading.

5C.2.2. *Calculation:*

Subtract the burette reading obtained in 4C.2.4 from the burette reading obtained in 5C.2.1.

$$\frac{\text{Difference between burette readings} \times 2 \times 10 \times 0.053}{\text{Weight of Sample}} \times 100 = \text{per cent of sodium carbonate}$$

$$\text{Per cent of sodium carbonate} \times 0.585 = \text{per cent of sodium oxide } (Na_2O)$$

$$\text{Per cent of sodium hydroxide as } Na_2O + \text{per cent of sodium as carbonate } Na_2O = \text{total } Na_2O$$

1951 Conference—Miami

Miami sunshine, Miami moonlight and Miami informality may not have fostered frenzied activity, but A.W.W.A. managed a good week's work as well as a good week's play between April 29 and May 4, when the Florida Section played host to the 71st and second largest conference in Association history. Of social and athletic activity there was full measure, but neither salt water nor sunshine kept many members away from Dinner Key Exhibition Hall when one of the 16 technical sessions was in progress. And perhaps because Dinner Key was sunbathed itself, most A.W.W.A.'ers spent their full days there, lounging in the "Patio of the Sections" or visiting the 131 boothsful of the newest and best in water works ware when they weren't at a session or committee meeting or en route to inspect the Miami water plant. Meanwhile, downtown, a record-breaking group of water wives *did* Miami from their base in the Lobby Lounge of the Columbus Hotel.

Responsible for the show as a whole was the Convention Management Committee, which, under the chairmanship of C. F. Wertz, included:

Representing A.W.W.A.

A. P. Black
M. R. Boyce, Sr.

Representing W.S.W.M.A.

T. T. Quigley
E. A. Sigworth

Ex Officio

W. V. Weir, *President*
H. E. Jordan, *Secy.*
C. H. Capen, *Chm., Publication Com.*
R. F. Orth, *President*
J. G. Stewart, *Mgr.*

Chief keeper of noses to the grindstone was Charlie Capen, who headed the committee which planned a 90-man program covering everything of moment to the water works field. What was said and by whom, formally and on schedule, is listed on pages 1032–34; what was written or recorded has already and will continue to be reported in the pages of the Journal; and what was asked, answered and said spontaneously must be imagined from the subjects themselves. Particularly were the sessions on national water policy, critical materials and defense, and on fluoridation popular and productive. But every session appealed most to a lot of people.

Minding business, too, was John Stewart's Exhibit Committee, which set up 131 booths and a "Patio of Sections" in the comfortable expanse of what was once a Pan-American and, later, a Navy hangar. There it was that manufacturers made operators' mouths water with the lusciousest in water works equipment and there it was that members shopped and shoptalked before, between and after sessions.

1951 CONFERENCE STATISTICS

Miami Registration by Days

Day	Men	Ladies	Total
Sunday, April 29	704	241	945
Monday, April 30	614	233	847
Tuesday, May 1	62	17	79
Wednesday, May 2	25	—	25
Thursday, May 3	10	—	10
TOTALS	**1,415**	**491**	**1,906**

Geographical Distribution of Registrants

UNITED STATES & TERRITORIES

Alabama	57
Arizona	9
Arkansas	11
California	89
Canal Zone	1
Colorado	10
Connecticut	17
Delaware	3
Dist. Columbia	18
Florida	192
Georgia	132
Hawaii	3
Illinois	139
Indiana	30
Iowa	28
Kansas	15
Kentucky	18
Louisiana	30
Maine	2
Maryland	22
Massachusetts	30
Michigan	36
Minnesota	31
Mississippi	2
Missouri	55
Nebraska	14
New Jersey	123
New Mexico	2
New York	172
North Carolina	53
North Dakota	6
Ohio	78
Oklahoma	9
Oregon	4
Pennsylvania	159
Puerto Rico	8
Rhode Island	16
South Carolina	25
South Dakota	6
Tennessee	39
Texas	56
Virginia	28
Washington	2
West Virginia	13
Wisconsin	39

CANADA, CUBA & FOREIGN

Brazil	1
Canada	29
Cuba	35
Dominican Republic	1
Mexico	4
Venezuela	4
TOTAL	**1,906**

Comparative Registration Totals—1942–1951

Year	Place	Men	Ladies	Total
1951	Miami	1,415	491	1,906
1950	Philadelphia	1,678	329	2,007
1949	Chicago	1,593	374	1,967
1948	Atlantic City	1,348	356	1,704
1947	San Francisco	1,115	431	1,546
1946	St. Louis	1,303	214	1,517
1944	Milwaukee	1,185	171	1,356
1943	Cleveland	973	158	1,131
1942	Chicago	1,198	240	1,438

Win, Place & Show in Section Awards

Henshaw Cup		Hill Cup		Old Oaken Bucket	
Canadian	**68.9%**	**Kansas**	**40.96**	**California**	**916**
Rocky Mt.	63.4%	Florida	34.82	New York	666
Montana	62.1%	Indiana	33.48	Southwest	617

Supervising the fun fare were Tom Quigley and his General Entertainment Committee, who managed to keep everyone happy every evening and all the ladies, all day—no easy assignment anywhere. Beginning with "Meet & Greet Night" on Sunday and finishing with the annual dinner and dance on Thursday, there were receptions, dances, concerts, variety shows, golf tournaments, teas, boat trips and even a fun fashion show. And every event was blessed not only with good planning but good Miami weather.

Getting them there and back home again, directly or deviously as required, and even getting a number to Havana after the conference was over, was "Wheels" Sigworth cracking the whip over his Transportation Committee. Big wheels, too, in keeping things rolling smoothly were all those guys and gals who had Florida tans before the conference. Caesar Wertz we've already mentioned, but there were also Maestros W. A. Glass and H. E. Keating of the Local Arrangements Committee; Dave Lee and Keith Keller as heads of the hosts for old-timers and freshmen, respectively; and A. B. Kononoff and H. H. Hyman of the local publicity and transportation committees. But those weren't all by any means. All the members of the Florida Section and all their wives did big bits to make this not only an A.W.W.A. year to remember, but a place to file and not forget.

Association Awards

Honorary Membership was conferred upon Charles R. Cox of Albany, N.Y.; Samuel B. Morris of Los Angeles, Calif.; and Sheppard T. Powell of Baltimore, Md. The citations follow:

Charles Raymond Cox, Chief, Water Supply Section, Bureau of Environmental Sanitation, State Department of Health, Albany, N.Y.; a member of the Association since 1921; Fuller Award 1940; Director, New York Section 1941–44; Chairman, New York Section 1940–41; Secretary, Water Purification Division 1935–47; A.W.W.A. representative on Advisory Committee to U.S. Public Health Service for Revision of Drinking Water Standards; cooperator in revision of *Water Quality and Treatment*. *An effective servant of the people of New York, whose professional competence and teaching ability have led to long range improvement in public water supply quality in his state and over the nation.*

Samuel Brooks Morris, General Manager and Chief Engineer, Los Angeles Department of Water and Power; previously Dean of Engineering, Stanford University; a member of the Association since 1920; Diven Medal, 1933; A.W.W.A. President 1944; Director, California Section 1930–33; Secretary-Treasurer, California Section 1923–25; Vice-President, California Section 1926; President, California Section 1927; member, A.W.W.A. Committee on National Water Policy; member (1950), President's Commission on Water Resources Policy. *The chief executive of a great publicly owned water and electric utility whose engineering ability, business courage and genuine human qualities make him an honored leader of men.*

Sheppard Tappen Powell, Consulting Engineer, Baltimore, Md.; a member of the Association since 1906; Fuller Award 1947; Chairman, Water Purification Division 1935; associated with the preparation of various editions of

Standard Methods; contributor to revision of *Water Quality and Treatment;* organized the Joint Committee on Boiler Feedwater Research and served as its Chairman from 1925 to 1935. *An international authority in the production and control of quality of boiler and process waters, whose services have contributed greatly to the industrial potential of this country.*

The John M. Diven Medal, awarded to the member whose services to the water works field during the past year are deemed most outstanding, was presented to Wendell R. LaDue. The citation follows:

WENDELL RICHARD LADUE, for his conduct of the activities of the Committee on Water Works Administration; his service as General Chairman of the Committee since its organization in 1947; his selection of key men for subcommittee leadership; and his stimulation of committee work—all of which have brought credit to him and to the Association.

The John M. Goodell Award, granted for the best paper published in the JOURNAL, was presented to:

MALCOLM STRONG MCILROY, for his paper entitled "Direct-Reading Electric Analyzer for Pipeline Networks" which was published in the April 1950 issue of the JOURNAL, (Vol. 42, page 347). The research work done in connection with development of the analyzer was of the highest order and the value of the results will continue to be of great importance to the profession. Professor McIlroy is to be highly commended for his lucid presentation of such a difficult subject.

The Committee gave honorable mention to the paper by John R. Baylis entitled "Experience With High-Rate Filtration" which was published in the July 1950 issue of the JOURNAL (Vol. 42, page 687); and the paper by Walter H. Cates, entitled "Design Standards for Large-Diameter Steel Water Pipe" which was published in the September 1950 issue of the JOURNAL (Vol. 42, page 860).

The George Warren Fuller Awards were presented to twenty-five men whose Sections had nominated them in the year beginning with the 1950 Philadelphia Conference and ending with the opening of the 1951 Conference at Miami. The awards—which are presented for "distinguished service in the water supply field and in commemoration of the sound engineering skill, the brilliant diplomatic talent, and the constructive leadership of men in the Association which characterized the life of George Warren Fuller"—went to the following list of awardees:

Alabama-Mississippi Section—GEORGE HANSEL GODWIN: For his intelligent management of the water supply works of his city; and for his many services to his associates in the water works field.

Arizona Section—DARIO TRAVAINI: Early organizer, perennial officer and committeeman of the Section; nationally influential sanitary engineer; devoted public servant of his own and many other communities; a courageous leader of men.

California Section—WILFRED FRANCIS LANGELIER: In recognition of his spirit of research—which he has instilled into his students; and in further recognition of his many professional contributions to the art of water treatment—all in a spirit of uncommon humility and devotion to his chosen work.

Canadian Section—IRA PERCY MACNAB: For effective leadership within the Section; for notable achievement in water works management in the Maritime Provinces; and as the prime mover in the organization of the first Branch in the Canadian Section.

Chesapeake Section—WILLIAM DENNIS COLLINS: In recognition of eminent service in the field of water chemistry; his pioneering leadership in the advancement of knowledge of the chemical characteristics of the water supplies of the United States; and for his active interest in the Association.

Cuban Section—MANUEL J. PUENTE: For his exceptional engineering capacity; for his untiring efforts in bettering water works design in Cuba manifest in his participation in the plans for reconstruction of the Havana Water Works; and for his high ethical standards in resolving water works problems in Cuba.

Florida Section—THOMAS PAUL: For diligent work in the improvement of maintenance and operation of water works plants; and his aggressive efforts on behalf of the Section.

Illinois Section—JESSE JOHN WOLTMANN: A consulting engineer of excellent repute in the field of sanitation, who has given of his time, efforts, and energy for the improvement of the Section's activities by his willingness to serve on many committees and in various offices.

Indiana Section—HOWARD WILLIAM NIEMEYER: For valuable service to the Indiana Section; his careful analysis and effective reporting of operating experience in the fields of distribution system operation and maintenance; and his improvements of customer services and metering with resultant improvement in water works practice.

Iowa Section—EDWARD BARTOW: In recognition of a lifetime of inspiration to all who know him; for his leadership in education and research; and in tribute to his fine personality and his great qualities as a citizen.

Kansas Section—ROBERT HARLAN HESS: For his able leadership in Section affairs; for his contribution through water works schools and professional literature; and for his interest in water works research.

Michigan Section—JACK ELLIS COOPER: For his outstanding leadership in the education and training of water treatment plant personnel through university inservice training; selected technical and extension courses of instruction.

Missouri Section—NATHAN THOMAS VEATCH: In recognition of the services he has rendered to the water supply industry, to the individuals working in the water works field, and to the public—all beyond the call of his many responsible, professional duties.

New England Section—KARL RAYMOND KENNISON: In recognition of his outstanding skill in the field of water works design and construction; and to honor his high and fearless standards of professional integrity.

New Jersey Section— C. B. TYGERT: For his outstanding service to the New Jersey Section, as a loyal member, a tireless worker and a most capable secretary.

New York Section—LINN HARRISON ENSLOW: For his meritorious work in the development of water chlorination; the spreading of knowledge upon the design, construction, and operations of water works; and his industrious and valuable participation in the activities of the Association.

North Carolina Section—Robert Stanley Phillips: For his untiring efforts for the betterment of the North Carolina Section as its Secretary-Treasurer, and editor of its Journal; for his outstanding leadership in connection with operators' schools; and for his willingness to share his knowledge with others.

Ohio Section—Luther Thomas Fawcett: For his loyal interest, outstanding cooperation, and inspiring leadership in Section affairs; and for his many services to the Section.

Pacific Northwest Section—Winston Headly Berkeley: For distinguished service in the field of water purification, especially the fluoridation of water supplies. A man who lives in the spirit of his work, always devoted to the advancement of the water works field.

Pennsylvania Section—Carleton Emerson Davis: In recognition of a distinguished career of more than a half century in the planning, construction and operation of public water supplies notably in the Panama Canal area and in the great metropolitan areas of New York City and Philadelphia; and for his long and continuing service to the Association.

Southeastern Section—Robert Brittain Simms: For his leadership in the organization of the Southeastern Section; for his thirty years of distinguished service to the city of Spartanburg in providing through foresighted planning and efficient management, a safe and adequate water supply for all purposes.

Southwest Section—John Henry O'Neill: In recognition of thirty-six years of distinguished service as a state sanitary engineer, contributing to the advancement of water works practice as an organizer of educational programs for water works personnel; and as founder of the Louisiana Conference on Water Supply and Sewerage.

Virginia Section—Percy Harold McGauhey: For his promotion of engineering skills; for his past inspiration to young engineers; and for his distinguished career and active interest in the Virginia Section for which he has given freely of his energy and time.

West Virginia Section—Paul Dudley Simmons: In recognition of his outstanding work in the field of water purification; for fine service to his community and for leadership in water works organization in the state.

Wisconsin Section—Oswald John Muegge: For his continuous and unfailing interest in and support of the activities of the Wisconsin Section, especially in relation to the water works operators school; and for his active efforts in improving the status of the professional engineer.

Schedule of Conference Papers and Reports

Open Session—10:00 A.M.—April 30, 1951

Committee on Water Works Practice............................L. R. Howson, *Chairman*
Committee on Water Works Administration.................Wendell R. LaDue, *Chairman*

Water Works Management Division—2:00 P.M.—April 30, 1951

Meter Maintenance Costs..A. P. Kuranz
Meter Reading and Billing Costs......................................Kenneth K. King
Automotive Equipment Costs..James B. Ramsey
Committee Report—Water Rates.............................Louis E. Ayres, *Chairman*

Water Purification Division—2:00 P.M.—April 30, 1951

Soluble Copper Salts for Water Treatment............................Marsden C. Smith
Continuous Odor Monitor and Threshold Tester............................H. H. Gerstein
Committee Report—Disposal of Purification Plant Wastes..W. W. Aultman and A. P. Black
Committee Report—Specifications for Water Treatment Chemicals......................
James E. Kerslake, *Chairman*
Committee Report—Standard Methods for the Examination of Water and Sewage..........
Ray L. Derby, *Chairman*

General Session—9:30 A.M.—May 1, 1951

Water Pipe Joint Rings Compounded With Synthetic and Natural Rubber......W. L. White
Applications of the Heat Pump..N. C. Ebaugh
Discussion...Claude R. Erickson
Some Illustrations of the Value of Analyzing Pipe Networks..........Malcolm S. McIlroy
Recent Research in the Performance of Sulfur Jointing Compounds......................
Raymond B. Seymour and Walter Pascoe

Water Purification Division—9:30 A.M.—May 1, 1951

Studies on the Removal of Radioisotopes by Water Treatment Processes.......Rolf Eliassen
Discussion..Arthur E. Gorman
Discussion..H. Gladys Swope
Instrumentation of the Water Examination Laboratory............................S. K. Love
Discussion..Edward S. Hopkins
Further Research in Diatomite Filtration........Joseph M. Sanchis and John C. Merrell Jr.
Discussion..John E. Kiker

Water Works Management Division—2:00 P.M.—May 1, 1951

Committee Report—Compensation of Water Works Personnel......Leon A. Smith, *Chairman*
Payment for the Cost of Utility Changes in State Highways.................Harry B. Shaw
Committee Report—Safety Program for Water Works.........Raymond J. Faust, *Chairman*

Water Purification Division—2:00 P.M.—May 1, 1951

Studies in Local Production of Chlorine...........Charles A. Black and Carl M. Hoskinson
Lime Reclamation at the Miami Softening Plant.............................C. F. Wertz
Discussion..H. V. Pedersen
Discussion..Anthony J. Fischer
Panel Discussion—Fluoridation Practices...
Led by Jerome Zufelt, H. T. Dean and Otto M. Smith

General Session on National Water Policy—9:30 A.M.—May 2, 1951

The Report of the President's Water Resources Policy Commission........Samuel B. Morris
Water Policy as the Engineers See It.......................................Abel Wolman
Objectives of a National Water Policy....................................Malcolm Pirnie
Local and Regional Water Supply Management..............................Harry E. Jordan
Discussion..Dale L. Maffitt
Discussion..A. G. Matthews
Discussion..Fred Merryfield

Water Resources Division—2:00 P.M.—May 2, 1951

Panel Discussion—Safe Yield of Ground Water Sources:
Introduction..Malcolm Pirnie
Geologic and Hydrologic Factors...............................V. T. Stringfield
Miami Water Supply..G. G. Parker
Construction and Operation of Wells...........................Paul Schweitzer
Discussion..A. P. Black
Discussion..W. A. Glass
Discussion..R. M. Leggette

Committee Report—Recommended Practice for Sealing Abandoned Water Wells........... James C. Harding, *Chairman*
Mortality of Water Wells..............................Herbert E. Hudson and J. L. Geils
Discussion..A. E. Fawcett
Discussion..H. E. Lauman
Discussion..W. A. McEllhiney

General Session—9:30 A.M.—May 3, 1951

Industry's Water Requirements...Roy R. Green
Characteristics of Water Use in the United States......................William F. Guyton
Discussion..E. B. Showell
Discussion..D. J. Saunders
Family Income and Residential Water Consumption. . Herbert E. Hudson and Bernt O. Larson
Fluctuations in Water Use and Revenue..
W. G. Banks, Walter Boquist, Richard Bonyun and H. M. Ohland

General Session—9:30 A.M.—May 4, 1951

Panel Discussion—Water Works and the Defense Program...............................
N. S. Bubbis, Earl Devendorf, Burton S. Grant, Harvey S. Howe, George S. Moore, Frank J. Schwemler, Harry B. Shaw, Thomas J. Skinker and Paul Weir
Critical Materials, Priorities, Allocations.....................*Led by* Wendell R. LaDue
Civilian Defense...*Led by* John S. Longwell
Radio as an Emergency Aid.............................*Led by* Morrison B. Cunningham

Papers Scheduled at 1951 Section Meetings

THERE follows a summary listing of papers scheduled for presentation at 1951 Section Meetings. The dates of the Section Meetings from 1947 to 1951 and the locations for 1951 are listed on page 1046. Section officers who were elected at meetings held during 1951 are listed on page iv in the front of this issue. The programs are listed alphabetically by sections, without regard to the date of presentation.

Alabama-Mississippi Section—September 25-26, 1951

Address of Welcome..*Mayor* R. Hart Chinn
Response..Tip H. Allen
Coordination of Activities of Municipal Departments........................Ed E. Reid
Public Relations..Lewis M. Smith
Safety..L. F. Scott
Procurement of Critical Materials for Water Works........................Martin Kunkel
Public Health Aspects of Atomic Explosion........................Henry J. L. Rechen
Status of Water Works Operators Certification in Alabama............Gilbert H. Dunstan
Current Water Works Problems..A. E. Berry
Panel Discussion—Maintenance of Distribution Systems and Records........................
W. H. H. Putnam and Alex O. Taylor
Panel Discussion—Fluoridation of Public Water Supplies..H. A. Kroeze and Arthur N. Beck
Civilian Defense..H. M. Gostad
Pipeline to the Clouds..*A Motion Picture*

Arizona Section—March 28-31, 1951

Greetings..H. C. Bryant
Response..George W. Marx
Wood Preservation..W. E. Hoyt
Hydropneumatic Pressure Tank Installation........................Harry S. Jordan
Redevelopment of Water Wells by Vibratory Explosives........................Harvey Nylander
Trenton Cleans Its Water Mains..*A Motion Picture*
Civil Defense and Water Supplies..Samuel B. Nelson
Disposal of Wastes From Water Purification and Softening Plants..........W. W. Aultman
Biological Warfare..H. Gilbert Crecelius
Symposium—Protective Coating of Pipe...............N. K. Senatoroff and Roy Richards

California Section—October 23-26, 1951

Address of Welcome..*Mayor* Elmer E. Robinson
Response..G. E. Arnold
Features of the San Francisco Water System........................S. M. Tatarian
Economics of Making Replacements, Enlargements and Additions to Plant Facilities........
Eugene L. Grant
Crushing Strength of Cement-Mortar Lined and Coated Steel Pipe as Determined by Field Tests..Leslie Paul and O. F. Eide
Discussion..Harold L. White
Timekeeping—An Administrative Tool..J. W. Franklin
Budget Control..Lauren W. Grayson
Discussion..W. C. Renshaw
Discussion..Harold L. May
Handling Damage Claims..Carroll Clark

Panel Discussion—Public Relations in Practice..........Carl F. Mau, John W. McFarland, Brennan S. Thomas, Norman Andrews and Philip F. Walsh
Improvement of Wells by the Use of Vibratory Explosives............Harvey A. Mylander
Panel Discussion—Cathodic Protection:
Design Calculations for Cathodic Protection of Pipelines................W. R. Schneider
Cathodic Protection of Steel Water Storage Tanks in Long Beach......C. Kenyon Wells
Magnesium Anodes for Cathodic Protection of Pipelines and Tanks........L. E. Magoffin
Testing and Repairing of Water Meters 2-in. and Smaller..................O. G. Goldman
Building Water Rate Structures..Everett L. Clark
Classification of Water Systems for Fire Protection........................Loren S. Bush
Panel Discussion—Regulations Governing Utilities in Roads............................ G. F. Hellesoe, Morris Burke and Norman Beenfeldt
Panel Discussion—Well Water Pollution in the Central Area of the South Coastal Basin:
The Los Angeles Regional Board Viewpoint..........................Linne C. Larson
The Water Utility Viewpoint...Philip Abrams
Water Quality Standards..J. E. McKee
Stable Indicator Solutions for the Determination of Calcium in Water..Harold Leon Fruitman
The Use of Molecular Filters for Simple and Rapid Bacteriological Water Examination..... Alexander Goetz
Discussion..Paul Kabler
Discussion..Lee Streicher
Discussion...Harry G. Neumann
Use of Sea Water for Regeneration of Resinous Cation Exchangers of Ventura Water Softening Plant...Hugh M. Wood
Design and Construction of Impervious Membranes for Excavated Reservoirs..J. W. Trahern
Regulations Governing Procurement and Use of Critical Materials in Water and Sewerage Works...Harry E. Jordan
Discussion...Gerald E. Arnold
Industrial Quality of Public Water Supplies in the West....................C. S. Howard
The Present Economic and Technical Status of Water Reclamation...................... H. B. Gotaas and R. V. Stone Jr.
Ground Wire Attachments to Water Pipe..................................R. C. Kennedy
Low Level Counting Techniques and Removal of Radioactivity From Water Supplies....... H. Gladys Swope
Panel Discussion—Geophysics and Water......................*Led by* John F. Stickel Jr.
Discussion on Seismic Methods.....................................Loren E. Blakeley
Discussion on Electrical Resistivity Method...............................B. B. Gordon

Canadian Section—May 21–23, 1951

Symposium—Civil Defense and Water Works:
The Importance of Water Supply and Protective Measures for Civil Defense............. W. E. MacDonald
Organization of Metropolitan Water Works for Civil Defense..............W. D. Hurst
Water Works Planning for Civil Defense in the Maritimes................Ira P. Macnab
Water Works Planning for Civil Defense on the West Coast.................J. C. Oliver
Guided Discussion—Water Works Practice in Western Canada......*Led by* W. E. Robinson
The Design and Construction of the New Greater Winnipeg Water District Booster Pumping Station.................................N. S. Bubbis and H. Shand
Factors Influencing the Efficiency of Activated Carbon...................D. C. Colebaugh
Saving in Power in Pumping Charges by Zones..........................R. B. Chandler
Guided Discussion—Problems in the Distribution of Water............*Led by* W. M. Scott
Guided Discussion—Planned Maintenance of Water Works Equipment.................... *Led by* C. G. R. Armstrong

Canadian Section—Maritime Branch—September 11–12, 1951

Guided Discussion—General Operation of a Water Works System......*Led by* G. Fournier
Lime Treatment and the Halifax Water Supply.............................G. L. Renner

Panel of Experts in Open Forum................................*Led by* J. D. MacKay, A. T. MacDonald, W. A. Devereaux and J. W. Churchill
Guided Discussion—Record Keeping and Accounting...............*Led by* J. C. McLellan

Chesapeake Section—October 31–November 2, 1951

Pipeline to the Clouds...*A Motion Picture*
Control of Water Quality for Cooling Systems.....................................J. Foley
Discussion..C. S. Bilisoly
Operating Kinks....................George Harrington, John Krasauskas and Jack Jester
Allocations and Priorities..Harvey S. Howe
Maintenance of Distribution Systems................................D. H. Goldsborough
Construction Experience With Pressure Pipe and Joints.....J. E. Farrell and R. S. Jackson
Membrane Filter in Sanitary Bacteriology..............................Harold J. Jeter
Discussion..Charles Phillips
Discussion..John Krasauskas
Selection and Treatment of Water for Industrial Use..........................S. T. Powell
The Proposed Ashburton Filtration Plant for Baltimore......................Roy H. Ritter

Cuban Section—November 29–December 1, 1951

Address of Welcome...*Mayor* Nicolas Castellanos
Address of Welcome..Manuel J. Puente
Hydrological Behavior of the Cuban Geological Formations..............Jorge Broderman
Methods Used in the Calculation of the Gilbert Arch Dam...........Jesus M. Valdes Roig
Stream Flow and Level Measurement at Aguada del Cura and Vento. Petrographic and Water Analysis..Abel Fernandez
Per Capita Costs of Cuban Water Works..................................Sergio Martinez
Theoretical and Experimental Study on the Specific Yield of the Southern Underground Basin of Havana Province............................J. Ignacio Garcia Bengochea
Deep Well Pumps—Their Characteristics and Selection.........................Luis A. Nunez

Florida Section—October 28–31, 1951

Invocation..Rev. Jack Davis
Address of Welcome...*Mayor* Ollie Lancaster
Response..Sidney W. Wells
A.W.W.A. Activities..Charles H. Capen
Panel Discussion—Corrosion in Water and Sewage Plants..............*Led by* Al Kimmel
Corrosion of Iron and Some Ferrous Alloys During the Sulfur Cycle....Armin H. Gropp
Practical Experience With Cathodic Protection of Water and Sewage Plant Equipment... Frank P. MacDonald
Corrosion Prevention—Progress of Research in the Field...................Al Kimmel
One Year's Operation of the Orlando Biolfiltration Sewage Treatment Plant..Mason S. Nagel
Discussion..Albert O'Neall
Four Years' Work at the Sanitary Research Laboratory of the University of Florida........ Wilson T. Calaway and Thomas deS. Furman
Discussion..David B. Lee
Materials Allocations...T. T. Quigley
Distribution of Water in the Central and Southern Florida Project........Harold A. Scott
Round Table Discussion—The Relation of Flood Control to Water Resources............. *Led by* A. G. Matthews, Robert O. Vernon, A. O. Patterson and Nevin D. Hoy
State Regulation of Water Utilities...............................William F. Whitney
Discussion..Robert E. Stiemke
Fundamental Considerations in Establishing Rate Differentials Inside and Outside City Limits..F. Burton Smith
Oxidation of Sulfides by Chlorine in Dilute Aqueous Solutions...........James B. Goodson
Discussion.......................................Eskel Nordell and A. P. Black
Guide for Selection of Chemical Feeding Equipment....................P. A. Coffman, Jr.

Safety Practices in Water and Sewage Plants.............................A. P. McIntosh
Municipal Consultants Service.................................Townsend Wainwright
Round Table Discussion—Stream Pollution Control in Florida and Neighboring States.....
Led by David B. Lee
Alabama...Arthur N. Beck
Georgia...William Weir
South Carolina..W. T. Linton
U.S. Public Health Service ....Lewis A. Young
Florida...David B. Lee

Illinois Section—March 28–30, 1951

Evaluating Fire Protection—Water Supplies.................................A. H. Gent
Water...Ellsworth Filby
Continuous Odor Tester...H. H. Gerstein
A New Philosophy in Water Treatment......................................C. W. Klassen
The Ideal Lime-Softened Water..T. E. Larson
Round Table Discussion—Civil Defense.................*Led by* Henrietta Herbolsheimer
Missouri..L. E. Ordelheide
Iowa..Dale L. Maffitt
Wisconsin...Leon A. Smith
Indiana...B. A. Poole
Illinois..C. W. Klassen
Availability of Water Works Materials....................................Harry E. Jordan
Water Rates...Louis E. Ayres
Round Table Discussion—Distribution System Maintenance and Repairs:
Mains and Services..S. T. Anderson
Meters..A. P. Kuranz
Valves and Hydrants...Clifford Fore
Elevated Tanks and Reservoirs...Frank C. Amsbary, Jr.
Reservoir Silting in Illinois......................*Lantern Slides presented by* J. B. Stall
Balancing Water Works Budgets.........*A Motion Picture presented by* Joseph O. Fortin
Discussion..Glenn Shehee
Furnishing Chicago Water to Outlying Municipal Districts...............Loran D. Gayton

Indiana Section—February 7–9, 1951

Pros and Cons of Fluoridation..O. J. Muegge
Discussion..George Fassnacht
Discussion..L. J. Beckman
The Economics of Water Softening...Louis R. Howson
Discussion..Dave Backmeyer
Discussion..Tom Burrin
Discussion..Tom Driskell
Problems Common to Public and Industrial Water Supplies..................Alfred O. Norris
Planning Future Expansions to Meet Public and Industrial Requirements.....Paul D. Cook
Quality Control of Industrial Water Supplies.............................Clarence D. Adams
Industry's Growing Water Problem ....Herbert Young
Mayor's Responsibility to His Water Works................................Clarence F. Hill
Civilian Defense and Mutual Aid in Event of Atomic Bombings..............Wendell R. LaDue
Panel Discussion—Emergency Committee.........................*Led by* M. H. Schwartz
Learning the Hard Way..Leo Louis Jr.
Present Status of Water Works Licensing Bill.............................Henry B. Steeg
Use and Operational Control of Mechanical Equipment.......................John Rian
Discussion..Howard W. Niemeyer
Discussion..M. H. Schwartz
Question Period ....*Led by* A. B. Daugherty

Iowa Section—October 25–27, 1951

Address of Welcome..*Mayor* Romolo Russo
Response..Mark Driftmier
Tales of South America..J. J. Hinman Jr.
Mechanical Joints for Cast-Iron Pipe..Thomas F. Wolfe
Regulations Governing Water Pipe Installations in State Highways............W. E. Jones
Valve Placement and Records..R. D. McGill
Is Your Well Going Dry?..Tom C. Thorpe
Panel Discussion—Taste and Odors in Water........................*Led by* M. E. Rew, J. A. Sampson, J. F. Erdei and George Lee
Fundamental Studies of Taste and Odor in Water Supplies..............F. M. Middleton
Research With Ozone for Taste and Odor Control.....................Marcus P. Powell
Corrosion Control of Softened Water..Paul Laux
Participating Panel...................Arnold Cherry, John R. Maloney and Ray Hoops
Water Service Installation Practice in Iowa............................H. V. Pedersen
Application of Fluorides to Water Supplies..............................O. J. Muegge
Salaries of Water Works Employees..Leon Smith
Questions and Answers..........................*Led by* P. F. Morgan, George C. Ahrens, Merlin H. Anderson, Robert L. Morris, J. A. Sampson and C. W. Varner
Discussion and Demonstration of Mobile Radio....J. Gordon Suor, Leo Louis and Joe J. Hail

Kansas Section—April 11–13, 1951

Welcome to Hays..Bernard J. Brungardt
Response..A. W. Rumsey
Water Section Round Table..H. H. Kansteiner
Trenton Cleans Its Water Mains..*A Motion Picture*
Supply Problems of Municipal Water Utilities in Kansas................Murray A. Wilson
Panel Discussion—Municipal Water Well Construction and Maintenance................. Ray E. Lawrence, E. J. Jungmann, Ted Guyer and D. R. Soder
Water Chlorination in Principle and Practice............................Harry A. Faber
Chlorinating Practices and Installations in Kansas.......L. H. Petersen and Joe Gyulay Jr.
Maintenance of Electrical Controls and Equipment in Water and Sewage Plants........... Maynard DeNeui
Standardized Mechanical-Joint Cast-Iron Pipe..........................Thomas F. Wolfe
Maintenance and Operation of Settling Tanks..........................William N. Konrad
Round Table..*Led by* V. A. Basgall
A New Method of Hypochlorination..J. J. Tepas
Water Meter Maintenance and Repair................W. H. Dominick and A. P. Flynn
Fluoridation of Public Water Supplies....................................Dwight Metzler
Thirty Years of Progress in Sewerage Practice..........................Earnest Boyce
Maintenance of Raw Water Quality Standards............................Albert E. Berry
Civilian Defense..Standish Hall

Kentucky-Tennessee Section—September 17–19, 1951

Address of Welcome..Henry Gerber
Address of Welcome...................................*Mayor* Charles P. Farnsley
Response..G. R. Kavanagh
Organization of Old Hickory Utility District............................H. B. Richards
Civilian Defense—Emergencies..Neil Dalton
Fluoridation of Tennessee and Kentucky Water Supplies..H. N. Jernigan and Carl L. Sebelius
Management of a Water Company..A. E. Clark
Panel Discussion—Obtaining Technical Services for Small Water Systems................ L. H. Clouser, Grant S. Bell, Earl Braybeal and Robert W. Williamson
Panel Discussion—Service Installations: Tapping Cement, Asbestos and Cement-Lined Pipe.. Robert Fisher, Joe Lovell, M. L. Brickey and James W. McAmis

Panel Discussion—How Fire Rates Are Set..
Rollie J. Bartlett, Victor Appleyard, Justin Davis and J. L. Thompson
Panel Discussion—Benefits of Short School Courses to Plant Management................
T. E. Jones, William H. Johnson, Elmer Smith and Odell W. Gray
Panel Discussion—Policies of Providing Water Service Beyond City Limits..............
C. M. McCord, E. E. Jacobson, B. E. Payne and Lois Sutherland
Panel Discussion—Effects and Cost of State Highway Construction Policies on Utility Installations..C. E. Eubanks and Jack Boxley
Effects of Upstream TVA Reservoirs on Waste Disposal at Kingsport, Tenn.............
M. A. Churchill
Planning the Expansion of Water and Sewerage Service..................Arthur L. Dow

Michigan Section—September 19–21, 1951

Address of Welcome..*Mayor* Waldo Tiscornia
Address of Welcome..*Mayor* F. Joseph Flaugh
Response..*Chairman* George Hazey
News of the Field...John E. Vogt
Symposium—Benton Harbor Water Filtration Plant....................................
Design...Paul H. Johnson
Operating Experiences...William J. Russell
Symposium—Air Conditioning and Refrigeration......................................
Problems of Water Works...Frank C. Amsbary, Jr.
Problems of Industry...A. E. Stacey, Jr.
Power and Water Demands...Hugh E. Keeler
Air Navigation Hazards From Elevated Structures.......................Lindell D. Hale
Water Supply as It Affects Fire Protection...............................R. C. Loughead
Further Studies of Chlorine Demand Constants........Douglas Feben and Michael J. Taras
Discussion...Harry A. Faber
Discussion...L. L. Hedgepeth
National Supply Problems...Raymond J. Faust
Calculation of the Effect of Temperature on pH............................John F. Dye
Safety Practices...George McDonald
Discussion...Lynn Erratt
Discussion...Earl Norman

Minnesota Section—September 12–14, 1951

Address of Welcome...*Mayor* Hoyer
Response..*Chairman* R. M. Jenson
Symposium—Iron and Manganese Removal..........................*Led by* W. R. Lawson
Fundamental Methods..A. S. Johnson
Panel Discussion—Relations Between Water Works Operators and City Officials..........
Led by Herbert S. Grove, C. C. Ludwig and LeRoy Harlow
Fishing in Alaska...*A Motion Picture*
Panel Discussion—The Repair and Maintenance of Meters.......*Led by* George A. Roden, Harold Foster, P. L. Eide and W. L. Wardrop
Civil Defense...E. B. Miller
Civil Defense and Public Water Supplies...................................Earl H. Ruble
Guided Discussion—Procedures in Handling Water Accounts............*Led by* Carl Flack
Hunting in Alaska...*A Motion Picture*
Fluoridation of Water Supplies...F. J. Maier
Fluoridation Experiences at Aberdeen, S.D...................................W. P. Wells
Symposium—Water Softening:
Zeolite...H. M. Mueller
Lime Soda...A. C. Janzig and Kermin Rude
Question and Answer Period.....................................*Led by* Jerome H. Svore

Missouri Section—September 30–October 2, 1951

Address of Welcome..*Mayor* Stanley I. Dale
Response..Frank Thierfelder
Procurement of Materials..Raymond J. Faust
The Keystone is the Foreman..Stephen C. Casteel
Protective Coatings for Metal Surfaces in Water and Sewage Plants...........H. J. Benjes
Pipeline to the Clouds..*A Motion Picture*
Rehabilitation of Water Wells..Ray O. Joslyn
Standardized Mechanical-Joint Cast-Iron Pipe..Thomas F. Wolfe
A Practical and Possible Civil Defense Program for Water and Sewage Plants.............
Ralph Hammond
The Effect of Atomic Warfare on Water and Sewage Plants..............Conrad P. Straub
Discussion—As the Division of Health Sees It..L. E. Ordelheide
Floods and a Disaster Plant..Melvin P. Hatcher
The Impact of Air Conditioning on Water Plant Operation..........Frank C. Amsbary Jr.

Montana Section—April 20–21, 1951

Address of Welcome..*Mayor* J. R. Kaiserman
Response..Joe M. Schmit
Round Table Discussion..*Led by* M. E. Henderson
Rain Increase Projects in Relation to Water Resources..Irvin G. Krick
Fluoridation of Public Water Supplies..F. I. Livingston
Critical Materials and Priorities..Raymond J. Faust
Frost Penetration in Montana..John Hall

Nebraska Section—April 19–20, 1951

Welcome..*Mayor* Victor E. Anderson
Equipment and Its Operation for Fluoridation of Water..E. G. Riepe
Fluoridation Installation Details..T. A. Filipi
Essential Utility Accounting Records..Vern Livingston
The Water Industry and the National Emergency..R. J. Faust
Public Relations for Utilities and Their Customers..Glen Walker
Trenton Cleans Its Water Mains..*A Motion Picture*
Panel Discussion—Mutual Aid in Emergencies..*Led by* John Cramer,
Phil Mockett, Max Powers, Bud Elliott, Harry Morris and Herbert Marshall

New York Section—April 5–6, 1951

Address of Welcome..*Mayor* Erastus Corning
Controlled Materials..W. Victor Weir
Relation of Water Utilities to State Regulatory Bodies..Spencer B. Eddy
Panel Discussion—Civil Defense and Mutual Aid..*Led by* Earl Devendorf
Statewide Problems..C. R. Cox
Zone Problems..James C. Harding
Local Defense Problems..Elon P. Stewart
Round Table Conference..*Led by* S. P. Carman
Control of Taste, Odor and Color by Excess Chlorination..............Thomas M. Riddick

New York Section—September 12–14, 1951

Symposium—Incodel Project..*Led by* James C. Harding
Precepts for Feeding Fluoride Chemicals to Water..L. E. Harper
Discussion on Fluoridation..Attmore E. Griffin
Panel Discussion on Materials Situation..*Led by* Harry E. Jordan
Manufacturers..T. T. Quigley
Water Works..James G. Carns Jr.
Government..Harvey S. Howe

Panel Discussion—Civil Defense.................................*Led by* Earl Devendorf
State...Edward W. Dayton
Zone...James C. Harding
City...Lewis B. Smith
Round Table Conference.............................*Led by* S. P. Carman
Taste and Odor Control.......................Charles R. Cox and Thomas M. Riddick
Factors Influencing the Efficiency of Activated Carbon..................H. F. Laughlin
Chlorine Dioxide...Harry A. Faber

New Jersey Section—October 25–26, 1951

Fundamental Considerations in Rate Structures for Water Works......W. James MacIntosh
Clean Streams...Milo F. Draemel
How Soil Management Affects Water Run-Off....................Wallace A. Mitcheltree
Showing of Water Works Kodachrome Slides............P. S. Wilson and Ralph L. Tyler
Description of New Meter Shop at Westfield..........................George M. Haskew
Description of New Meter Shop at Ridgewood.............................J. A. Carr
Liability Insurance as It Affects Water Works Operations................Harry J. Brady
Discussion...E. G. Ohlson
The Controlled Materials Plan...................................Harvey S. Howe
Requirements of the New Jersey Health Department of Fluoridation Installations..........
A. H. Fletcher
Civilian Defense Plans for New Jersey..........................Lawrence A. Greenberg
Forum—The New Jersey Pine Region—A Water Supply of the Future?..................
Introduction—New Jersey Looks to the Pine Region for New Sources of Water.........
Thurlow C. Nelson
Forest Succession in the Pine Region of N.J. as Influenced by Man...........M. F. Buell
Present Vegetation of the Pine Region and How Foresters Would Change It...Silas Little
How Foresters Are Now Attempting to Change the Vegetation of the Pine Region in the Interest of Better Lumber, Better Fire Protection and Water Supply.....E. B. Moore
Some Agricultural Uses of Water in the Pine Region of New Jersey.......Joseph Palmer

North Carolina Section—November 12–14, 1951

Invocation...Rev. C. Excelle Rozzelle
Address of Welcome..............................*Mayor* Marshall Kurfees
Winston-Salem Water Works.....................................Stanford E. Harris
Fluoridation Results From the Dental Viewpoint............................Z. M. Stadt
Panel Discussion—Meter Reading and Billing........*Led by* W. E. Long, W. M. Franklin, Stanford E. Harris, Robert Van Sleen and James M. Owens
Disposal of Radioactive Wastes in Water and Sewage......................Roy J. Morton
Maintenance of Water Quality...................................Albert E. Berry
The New North Carolina Stream Sanitation Law............................H. G. Baity
Service Charges in Relationship to Sewage Financing.....................D. M. Williams

Ohio Section—September 27–28, 1951

Round Table Discussion............*Led by* L. J. Hoffman, F. D. Kuckuck, Edwin J. Ward, Pierce Bailey, Thomas Lathrop, Richard Henderson and Carl A. Eberling
Round Table Discussion—Fluoridation...............................*Led by* A. S. Hibbs
Medical Aspects of Fluoridation...................................John W. Knutson
Mechanics of Feeding Fluorine...L. E. Harper
Research Engineer Views on Fluoridation...........................Martin E. Flentje
Fluoridation From the Operator's Viewpoint and That of the Public........L. H. Enslow
Round Table Discussion—Civil Defense.....................*Led by* George J. Van Dorp
An Editor Views Civil Defense................................W. A. Hardenbergh
What A.W.W.A. Can Do for You...................................Wendell LaDue
Public Health Aspects in Civil Defense..................................Fred Waring
Your Part in Local Civil Defense..................................Joseph F. More
Protection of Water Works......................................William W. Holst

Pacific Northwest Section—May 17–19, 1951

Address of Welcome...*Mayor* Fred J. Hume
Response...Elmo James
Radioactive Contaminants and the Public Water Supply..................W. A. McAdams
The National Production Authority and You...........................Philip M. Crawford
Water Quality Control in Canada...Albert E. Berry
Electric Flow Analyzers..C. L. Barker
Discussion...*Led by* Fred Merryfield
Filter Underdrain Systems...Winston H. Berkeley
Results at Lakeview, Wash., With Reverse Circulation Well Drilling.....John W. Robinson
Photogrammetry Use in Water Works.......................................Allen E. Hitchings
Panel Discussion—Meter Setting Methods..
William R. Bannecker, Fred D. Jones, Bert L. Terry and R. G. McGrady
Panel Discussion—Water Utilities Preparation for Civil Defense.........................
A. S. G. Musgrave, C. C. Casad, H. R. Vinson, Sydney J. Benedict and J. C. Oliver
The National Water Policy...J. C. Stevens
Public Relations and Public Utilities.......................................Harold J. Merilees
Remote Controls in Relation to Elimination of Surge and Water Hammer in Operation of Water Systems..John S. Shute
Panel Discussion—Water Service Program for Suburban Areas...........................
R. W. Morse, Mart Early and W. G. Wilmot
Some Angles of Water Works Financing..........W. A. Kunigk and John W. Cunningham
Mechanical Billing and Accounting...W. A. Shields

Pennsylvania Section—September 19–21, 1951

Trenton Cleans Its Water Mains...*A Motion Picture*
Washington Cleans Its Water Mains.....................................*A Motion Picture*
Improvements to Erie Filter Plants..D. E. Davis
Symposium—Industrial Water Supply, Quality, Conservation and Control.................
Led by L. L. Hedgepeth
General..Roy R. Green
Construction and Control..Robert W. Haywood Jr.
Water Supply for the United States Steel Co. Plant at Morrisville..........G. A. Howell
Waters of the Commonwealth..*A Motion Picture*
Civilian Defense..Richard Gerstell
Civilian Defense for Water Supply....................................John H. Murdoch Jr.
Factors Influencing the Efficiency of Activated Carbon................Joseph G. Filicky
Algae Control in Reservoirs..Martin Flentje
The Delaware River Basin Water Project..............................Francis A. Pitkin
Priorities of Water Works Materials..Harvey Howe
Discussion...James G. Carns Jr.
Symposium—Water Purification:
Ohio River...H. F. Holloway
Beaver River..E. C. Goehring
Monongahela River...Frank Bouson
Schuylkill River..John F. Kegebein Jr.
Delaware River...Elwood Bean
Water Hammer and Surge Suppression in Pipelines...........................Logan Kerr
Review of the Report of the Presidential Water Policy Commission...........Gilbert White
Rates for Water Service...W. James Macintosh

Rocky Mountain Section—September 24–26, 1951

Address of Welcome...*Mayor* Quigg Newton
Response...*Chairman* Charles G. Caldwell
The Current Problems of the Water Works Industry......................Harry E. Jordan
Fluoridation of Domestic Water Supplies.......................................Franz J. Maier

Handling and Feeding Fluorine Compounds.................................G. E. Riepe
Discussion...*Led by* Franz J. Maier
The Problem of Nitrate Contaminated Drinking Water...................Graham Walton
Water Disinfectant Dosages...George Schlitt
Reservoir No. 22 Dam...D. D. Gross
Pipeline to the Clouds..*A Motion Picture*
Small Water Supplies...Robert Cameron
Biological Warfare..John Richty
Civilian Defense Relating to Water and Sewage Facilities....................Terry Owens
Survival Under Atomic Attacks..Henry A. Larson

Southwest Section—October 15–17, 1951

Invocation...R. W. Jablonowski Jr.
Welcome Address...*Mayor* J. R. Edwards
Response...Karl Hoefle
Fort Worth Water System—Past, Present and Future........................Uel Stephens
The Inter-Agency Approach to a Comprehensive Study of the Arkansas-White-Red River Basins...L. W. Prentiss
Bacterial Warfare and Its Effect on Water Supply..................Vincent B. Lamoureux
Taste and Odors in Southwestern Surface Waters..........................J. K. G. Silvey
Panel Discussion—Civil Defense..*Led by* J. R. Pierce, Conrad P. Straub and Horace Sprague
Cooperation Between Utilities in Corrosion Control.....................H. H. Anderson
Regional Development of Water Supply in Texas Permian Basin.............S. W. Freese
Residual Chlorine Determination..Henry C. Marks
Panel Discussion—Materials Procurement.....................*Led by* M. B. Cunningham
Standpoint of Water Superintendents...................................Karl F. Hoefle
Standpoint of Contractors..R. M. Dixon
Standpoint of National Production Authority..........................Harvey S. Howe
College Water Plant Serves City and State........N. C. Burbank Jr. and Quintin B. Graves
Panel Discussion—Fluoridation..............................*Led by* Clayton H. Billings, Norman Gerrie, F. J. Maier and Burnell Waldrep

Virginia Section—November 7–9, 1951

Let's Seal Up Our Abandoned Wells......................................Paul Schweitzer
Municipal and Industrial Wells...Garland S. Sydnor
Drilling of Hard Rock Wells in Central Virginia.......................W. Calvin Falwell
Some Thoughts on Improving Water Supply Service.......................Linn H. Enslow
Discussion on Fluoridation...*Led by* H. E. Lordley
Panel Discussion—Civil Defense..*Led by* X. D. Murden
Communications...Larry H. Arnold
Inventories..W. Ray Odor
Mutual Aid and Mobile Support Groups.......................................J. H. Wyse
Current Problems of the Water Works Industry.........................Harry E. Jordan
Human Engineering...C. H. Rutledge
Atomic Energy Programs in Relation to Water Supply and Purification...Arthur E. Gorman
Continuing Maintenance—or Else!.......................................Wendell R. LaDue
Pneumatically Applied Cement Mortar in Water Works Structures.......Marsden C. Smith
Pipeline to the Clouds..*A Motion Picture*
Trenton Cleans Its Water Mains.......................................*A Motion Picture*
Symposium—New Water Works in Virginia.........................*Led by* E. C. Meredith
Staunton's New Plant..H. R. Knight
Norton's New Plant...R. K. McCord
Pulaski's New Plant..W. Martin Johnson
Wytheville's New Plant...F. O. Biehn

West Virginia Section—October 4–5, 1951

West Virginia and Its Natural Resources..............................*A Motion Picture*
Fundamental Studies of Taste and Odor in Water....................Frank M. Middleton
Biological Investigations in Water Pollution Control.......................W. M. Ingram
Summary and Significance of Water Commission Court Cases................T. J. Gillooly
Underground Arteries..*A Motion Picture*
Billing Methods for the Modern Utility............................Douglas H. Spaton
Fluoridation Round-Up:
Fluoridation Chemicals...R. W. Ockershausen
Laboratory Control of Fluoridation.......................................R. S. Jacobson
Fluoridation Installations at:
Wheeling..A. R. Todd
Weirton...Frank J. De Franco
Ripley...R. B. Parsons
Tokyo, Japan, Water Works..*A Motion Picture*
Observations on Operation of Upflow Clárifier for Turbidity Removal.........H. K. Gidley
Maps and Records of Distribution System Valves for Emergencies in War and Peace......
T. A. Stout
Civil Defense Activities and Water Works Materials Problems..........Raymond J. Faust
West Virginia Civil Defense Plan..Charles R. Fox

Wisconsin Section—September 25–27, 1951

Address of Welcome...*Mayor* Frank P. Zeidler
Controlled or Uncontrolled Fluoridation—A High or Low Dental Decay Rate for Your Community..John G. Frisch
Stream Pollution Control in Wisconsin..............................T. F. Wisniewski
Panel Discussion—Fluoridation and Stream Pollution..................................
Bruno J. Hartman, Andrew J. Marx, Norton A. Thomas and Harvey E. Wirth
Methods Used in Ground Water Studies in Wisconsin....................W. J. Drescher
Experiences in the Development of Ground Water Supplies in the Wausau Area............
Howard Potter
Panel Discussion—Ground Water Use...
E. F. Bean, A. Becher, Edward F. Kipp, William Leistikow and Thomas M. McGuire
Pattern for Survival...*A Motion Picture*
Some Aspects of the Problem of Radioactivity in Water Supply..........Arthur E. Gorman
Priorities and Procurement of Materials..............................Charles H. Capen
Panel Discussion—Radioactivity and Priorities...
E. W. Becker, O. J. Muegge and J. P. Schwada
Pipeline to the Clouds...*A Motion Picture*
Investigating the Condition of Underground Waterworks Structures in the Milwaukee Distribution System..Ervin C. Wickert
Essential Equipment for the Operation and Maintenance of Water Works Facilities........
E. M. Griffith
Report—Proposed Revision of the Statutes to Clarify the Authority of Utility Commissions..
Albert E. Hintz
Panel Discussion—Inspection and Maintenance..
R. E. Cannard, H. O. Londo, Joseph Lustig and Arthur Rynders

Section Meetings—1947–1951

Section	*1947*	*1948*	*1949*	*1950*	*1951*	*Meeting Place—1951*
Alabama-Mississippi	May 23–24	Oct. 13–15	Oct. 19–21	Oct. 11–13	Sept. 24–26	Biloxi, Miss.
Arizona	Oct. 9–11	Apr. 2–4	Apr. 1–3	Mar. 31–Apr. 2	Mar. 28–31	Grand Canyon, Ariz.
	——	Oct. 15–17	Nov. 11–13	Nov. 30–Dec. 2	——	——
California	——	Oct. 27–29	Apr. 29*	Apr. 21*	Apr. 6*	Santa Barbara, Calif.
	——	——	Oct. 25–28	Oct. 24–27	Oct. 23–26	San Francisco, Calif.
Canadian	Apr. 14–16	Apr. 12–14	Apr. 25–27	Apr. 3–5	May 21–23	Winnipeg, Man.
Chesapeake	——	——	Nov. 2–4	Nov. 1–3	Oct. 31–Nov. 2	Baltimore, Md.
Cuban	Nov. 20–22	Dec. 2–4	Dec. 1–3	Nov. 13–15	Nov. 29–Dec. 1	Havana, Cuba
Florida	Nov. 20–22	Nov. 18–20	Nov. 14–16	Nov. 13–15	Oct. 28–31	Daytona Beach, Fla.
Four States	Nov. 19–21	Oct. 20–22		——	——	——
Illinois	Apr. 17–18	Apr. 15–16	——	Apr. 12–14	Mar. 28–30	Chicago, Ill.
Indiana	May 7–9	Apr. 21–23	Apr. 20–22	Apr. 26–28	Feb. 7–9	Indianapolis, Ind.
Iowa	Oct. 9–11	Oct. 5–6	Oct. 6–7	Oct. 26–27	Oct. 25–27	Dubuque, Iowa
Kansas	Mar. 13–14	Mar. 11–12	Apr. 21–22	Apr. 19–21	Apr. 11–13	Hays, Kan.
Kentucky-Tennessee	Sept. 22–24	Aug. 23–25	Oct. 31–Nov. 2	Oct. 23–25	Sept. 17–19	Louisville, Ky.
Michigan	Sept. 18–20	Sept. 22–24	Sept. 28–30	Oct. 25–27	Sept. 19–21	St. Joseph, Mich.
Minnesota	Mar. 13–14	Sept. 1–2	Sept. 8–9	Sept. 6–8	Sept. 12–14	Minneapolis, Minn.
Missouri	Oct. 27–28	Oct. 24–26	Sept. 25–27	Oct. 1–3	Sept. 30–Oct. 2	St. Joseph, Mo.
Montana	Apr. 25–26	Apr. 9–10	Apr. 8–9	Apr. 21–22	Apr. 20–21	Helena, Mont.
Nebraska	Apr. 11–12	Apr. 22–23	Apr. 21–22	Apr. 13–14	Apr. 19–20	Lincoln, Neb.
New England	——	——	——	——	——	——
New Jersey	Feb. 19	——	Feb. 17	Feb. 15	Feb. 14	Newark, N. J.
	June 19	——	June 23	——	June 29	Trenton, N. J.
	Nov. 6–8	Nov. 4–7	Nov. 17–19	Oct. 26–28	Oct. 25–27	Atlantic City, N.J.
New York	Apr. 10–11	Apr. 1–2	Jan. 21	Jan. 17	Jan. 16	New York, N.Y.
	Sept. 4–5	Sept. 14–17	Apr. 28–29	Mar. 30–31	Apr. 5–6	Albany, N.Y.
	——	——	Sept. 6–7	Sept. 7–8	Sept. 13–14	Whiteface, N.Y.
North Carolina	Nov. 10–12	Nov. 8–10	Nov. 7–9	Nov. 13–15	Nov. 12–14	Winston Salem, N.C.
Ohio	Sept. 30–Oct. 2	Oct. 7–8	Nov. 3–4	Sept. 28–29	Sept. 27–28	Toledo, Ohio
Pacific Northwest	May 15–17	May 13–15	May 12–14	May 11–13	May 17–19	Vancouver, B.C.
Pennsylvania	——	——	Sept. 14–16	Oct. 18–20	Sept. 19–21	Philadelphia, Pa.
Rocky Mountain	Sept. 25–26	Sept. 15–17	Sept. 21–23	Sept. 27–29	Sept. 24–25	Denver, Colo.
Southeastern	Nov. 3–5	Dec. 6–8	Dec. 5–7	Oct. 23–25	——	——
Southwest	Oct. 12–15	Oct. 11–13	Oct. 10–12	Oct. 16–18	Oct. 14–17	Fort Worth, Tex.
Virginia	Nov. 17–18	Oct. 25–26	Oct. 24–25	Nov. 6–7	Nov. 7–9	Roanoke, Va.
West Virginia	Oct. 2–3	Sept. 30–Oct. 1	Sept. 22–23	Sept. 13–14	Oct. 4–5	Charleston, W.Va.
Western Pennsylvania	June 12–13	Oct. 20–22	——	——	——	——
Wisconsin	Oct. 23–25	Oct. 28–29	Oct. 11–13	Sept. 19–21	Sept. 25–27	Milwaukee, Wis.

* Regional meetings.

Section Membership at Time of, and Total Attendance at, Section Meetings—1947–1951

SECTION	1947		1948		1949		1950		1951	
	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance
Alabama-Mississippi	52	87	137	116	164	140	167	141	163	181
Arizona‖	26	134	41	159	69	181	83	93	72	154
California‖	726	§	770	1,133	826	831	947	1,267	1,028	1,252
Canadian	404	730	459	732	485	574	515	728	531	516
Chesapeake	*	*	*	*	209	196	245	149	247	119
Cuban	36	116	36	75	57	71	61	216††	65	52
Florida	165	116	190	103	216	174	240	216††	300	282
Four States	350	180	343	191**	#	#	#	#	#	#
Illinois	362	318	402	321	450	‡	459	284	470	348
Indiana	206	224	201	242	207	266	256	264	289	299
Iowa	93	115	95	157	102	138	109	242	115	195
Kansas	93	132	110	118	113	168	139	179	139	186
Kentucky-Tennessee	132	133	138	206	196	153	199	222	186	202
Michigan	199	222	232	248	254	211	284	214	294	225
Minnesota	161	206	172	322	182	169	208	177	216	167
Missouri	150	88	154	76	157	62	169	74	181	202
Montana	61	69	63	108	61	94	58	140	62	120
Nebraska	35	†	41	†	54	18	55	23	64	158
New England	172	‡	172	‡	187	‡	192	‡	205	‡
New Jersey‖	309	217	320	208	339	218	350	218	379	276
New York‖	627	230	644	200	643	250	682	†	715	340
North Carolina	169	212	174	238	171	226	176	222	178	242
Ohio	336	251	364	258	380	308	382	321	392	320
Pacific Northwest	267	234	264	260	277	267	295	330	299	257
Pennsylvania	*	*	*	*	345	147	390	182	419	214
Rocky Mountain	117	92	135	74	147	86	145	126	141	128
Southeastern	151	136	149	154	152	161	170	152	181	§
Southwest	557	428	558	545	659	618	678	795	702	708
Virginia	146	201	154	224	167	228	171	215	177	84
West Virginia	82	120	88	172	87	123	92	154	94	156
Western Pennsylvania	157	132	159	191**	#	#	#	#	#	#
Wisconsin	138	302	146	239	143	301	150	290	164	305

* Section not then organized.
† No record of attendance.
‡ No regular meeting scheduled. Membership given as of dates of conferences.
§ Regular meeting cancelled. Business meeting held at annual conference.
‖ Only one of section's meetings recorded here.
Section discontinued.
** Joint meeting, to form Chesapeake and Pennsylvania Sections.
†† Joint meeting.

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AMERICAN WATER WORKS ASSOCIATION

PUBLICATIONS

Effective January 1, 1952

Orders should be sent to the American Water Works Association, Inc., 521 Fifth Ave., New York 17, N.Y. Payment is required in advance, in U.S. funds, from nonmembers.

BOOKS

Index to Proceedings & Journal A.W.W.A. (1881–1939)—This cloth-bound, 285-p. index covers the Proceedings for 1881–1913 and the JOURNAL for 1914–1939. Price, for general sales, $2.00; to members paying in advance, $1.60.

Index to Journal A.W.W.A., 1940–1944—Paper-bound supplement to *Index to Proceedings and Journal A.W.W.A.* 64 pp. March 1945. Paper-bound. Price, for general sales, $1.00; to members paying in advance, 80¢.

Manual of Water Works Accounting—Prepared jointly by the A.W.W.A. and the Municipal Finance Officers Association, this 500-page Manual contains twenty chapters covering all utility accounting practices. 1938; 2nd printing, 1951. Price, for general sales, $4.00; to members paying in advance, $3.20.

The Quest for Pure Water—By M. N. Baker. A history of water purification from the earliest records to the 20th century. 73 illustrations, 900 references, 527 pp. 1948; 2nd printing, 1949. Price, for general sales, $5.00; to members paying in advance, $4.00.

Standard Methods for the Examination of Water and Sewage—Published jointly by the A.W.W.A. and the American Public Health Association. Cloth bound, 300 pages. Ninth edition, 1946. Available through the American Public Health Association, 1790 Broadway, New York 19, N.Y., at $4.00, net.

Survival and Retirement Experience With Water Works Facilities—Prepared by a joint committee of the A.W.W.A. and the Institute of Water Supply Utilities. Includes reports published in installments in JOURNAL, 1945–46, with additional material and summary tables. Cloth bound, 566 pp. 1947. Price, for general sales, $3.00; to members paying in advance, $2.40.

Water Quality and Treatment—A manual prepared by A.W.W.A. A comprehensive survey of water quality standards and procedures for purification, softening and other conditioning. Completely revised and enlarged second edition. 451 pp. 1950; 2nd printing, 1951. Price, for general sales, $5.00; to members paying in advance, $4.00.

Manual of British Water Supply Practice—A publication of the Institution of Water Engineers, London; distributed in U.S. by A.W.W.A. The essence of the water supply art, as practiced in Great Britain. Cloth bound, 900 pp. 1950. $7.50, net.

PERIODICALS AND PAMPHLETS

Journal American Water Works Association. A monthly magazine of technical papers, discussions, news and reports. Issued quarterly from 1914 to 1919; bimonthly from 1920 to September 1924; monthly ever since. Annual indexes are contained in the December issue of each year from 1940 on. Cumulative indexes of authors and articles grouped by topics are described on p. 1. Subscriptions only in conjunction with A.W.W.A. membership in U.S., Canada and Cuba, or $7.00 to libraries; not sold to individuals. Postage: to Canada, 20¢ additional; other foreign (except Pan-American Union), 80¢. Single copy price (of issues from 1925 on), for general sales, 75¢; to A.W.W.A. members, 50¢.

What Price Water? A brochure planned for the layman to explain expenditures for water utility operations and services. 14 pp., il., 25¢. (Quantity rates on request.)

Questions and Answers on Fluoridation of Public Water Supplies. An introduction to and explanation of the basic facts on a topic of wide current interest. No. 14 of the *Willing Water* series, April 1951. 4 pp., 5¢.

Willing Water. A catalog and price list of the *Willing Water* cartoon illustrations of the Willing Water cartoon illustrations available in electrotype or newspaper mat form, for use in printing and advertising work. No charge.

JOURNAL REPRINTS

Order by title and number, not by topic. Reprints are not normally furnished punched for loose-leaf binding. Copies of Journal articles not available in reprint form can generally be obtained by ordering a copy of the issue in which they were published; for terms, see "Journal A.W.W.A." in preceding "Periodicals and Pamphlets" section.

Air Conditioning. No. 263. Committee Report: Regulation of Air Conditioning and Other Refrigeration. Includes a suggested model ordinance regulating installation and operation of air-conditioning and refrigeration equipment. From December 1950 Journal. 9 pp., 20¢.

Annual Reports. No. 246. Committee Report: Water Department Annual Reports. Includes a guide to the preparation of an annual statistical report. From August 1950 Journal. 14 pp., 20¢.

Grounding. No. 270. A.W.W.A. Policy Statement: Grounding of Electric Circuits on Water Pipe. *Also* C. F. Meyerherm: Water Works Industry's Attitude on Grounding and Stray Current Problems. From April 1944 and December 1945 Journals. 4 pp., 10¢.

Main Extensions. No. 212. Committee Report: Water Main Extension Policy. From August 1949 Journal. 13 pp., 20¢.

Pension Legislation. No. 254. Committee Report: State Pension and Retirement Legislation in 1949. From October 1950 Journal. 8 pp., 15¢.

Pipe. No. 251. R. E. Barnard: Design Standards for Steel Water Pipe. From January 1948 Journal. 64 pp., 45¢.

Pipe. No. 248. W. H. Cates: Design Standards for Large-Diameter Steel Water Pipe. From September 1950 Journal. 27 pp., 30¢.

Radioactivity. No. 227. A. E. Gorman: Radioactivity—A New Factor in Water Works Practice. *Also* Placak & Morton: Research on the Disposal of Radioactive Wastes. From December 1949 and February 1950 Journal. 16 pp., 20¢.

Rates. No. 256. L. E. Ayres: Basic Considerations in Determining Water Rates. From November 1950 Journal. 22 pp., 25¢.

Regulations. No. 269. California Section Report: Tentative Regulations Governing Water Service. From April 1951 Journal. 14 pp., 20¢.

Resources. No. 278. Morris, Wolman, Pirnie and others. A series of reviews of the President's Water Resources Policy Commission Report. From June 1951 JOURNAL. 32 pp., 30¢.

Resources. No. 280. Roy R. Green: Water Use in Industry. From August 1951 JOURNAL. 12 pp., 20¢.

Resources. No. 194. Committee Report: National Policy on Water Resources. *Also* A.W.W.A. Policy Statement: Information Concerning Water Resources; *and* Executive Committee Statement: Allocation of Colorado River Water. From July 1948 JOURNAL. 8 pp., 15¢.

Resources. No. 244. Committee Report: Basic Water Use Doctrines and State Water Control Agencies. Includes a state-by-state survey. From August 1950 JOURNAL. 19 pp., 25¢.

Safety. No. 283. Task Group Report: Safety Practices. From June 1951 JOURNAL. 12 pp., 20¢.

Softening. No. 272. L. R. Howson: Economics of Water Softening. From April 1951 JOURNAL. 7 pp., 15¢.

Statistics. No. 221. W. B. Langbein: Municipal Water Use in the United States. From November 1949 JOURNAL. 5 pp., 15¢.

Statistics. No. 192. G. J. Schroepfer et al.: A Statistical Analysis of Water Works Data for 1945. From October 1948 JOURNAL. 32 pp., 30¢.

Treatment. No. 268. Committee Report: Capacity and Loadings of Suspended Solids Contact Units. From April 1951 JOURNAL. 29 pp., 30¢.

Writing. No. 271. A Style Manual for Journal Authors. Includes an explanation of editing and publication procedure; directions for preparing tables, illustrations and references for publication; a list of abbreviations used in the Journal A.W. W.A.; and tips on oral presentation. From the May 1947 JOURNAL. 16 pp., 20¢.

A.W.W.A. STANDARDS

EXPLANATORY NOTE: Effective October 31, 1951, the designations for A.W.W.A. standards (such as specifications, procedures and recommended practices) were revised and systematized. A full explanation of the system adopted may be found in the October 1951 Journal A.W.W.A., Vol. 43, p. 851. To minimize confusion, both the old and the new designations will be carried on publications lists and on the specifications themselves for a considerable period. Use of the new system is encouraged, but orders may be placed and will be filled on either basis.

A—Source

AWWA A100-46 (formerly 4A.1-1946)—**Standard Specifications for Deep Wells.** Approved as Tentative on April 30, 1945, and published in the September 1945 JOURNAL. Made Standard on May 10, 1946. 50 pp., 45¢.

B—Treatment

B100—Filtration

AWWA B100-50 (formerly 5C-1950)—**Standard Specifications for Filtering Material.** Revision of 1943 document approved as Tentative Nov. 15, 1948, and published in the March 1949 JOURNAL. Made Standard Jan. 16, 1950. 16 pp., 20¢.

B200—Softening

AWWA B200-49T (formerly 5W1.01-1949)—**Tentative Standard Specifications for Sodium Chloride.** Approved as Tentative Jul. 6, 1949, and published in the Mar. 1950 JOURNAL. 10 pp., 20¢.

AWWA B250-51 (formerly 5Z-1951)—**Standard Manual of Cation Exchanger Test Procedures.** Revision of 1943 document approved as Tentative Dec. 31, 1948, and published in the May 1949 JOURNAL. Made Standard May 4, 1951. 28 pp., 30¢.

B400—Coagulation

AWWA B400-49T (formerly 5W1.10-T-1950)—**Tentative Standard Specifications for Ammonium Sulfate.** Approved as Tentative July 15, 1949, and published in the Nov. 1950 JOURNAL. 7 pp., 15¢.

AWWA B401-50T (formerly 5W1.30-T-1950)—**Tentative Standard Specifications for Bauxite.** Approved as Tentative Apr. 28, 1950, and published in the July 1950 Journal. 8 pp., 15¢.

AWWA B402-49T (formerly 5W1.31-T-1950)—**Tentative Standard Specifications for Ferrous Sulfate.** Approved as Tentative May 31, 1949, and published in the October 1950 Journal. 7 pp., 15¢.

B500—Scale and Corrosion Control

AWWA B500-50T (formerly 5W1.60-T-1950)—**Tentative Standard Specifications for Trisodium Phosphate.** Approved as Tentative Apr. 3, 1950, and published in the June 1950 Journal. 6 pp., 15¢.

AWWA B501-51T—Tentative Standard Specifications for Caustic Soda. Approved as Tentative Oct. 15, 1951, and published in the December 1951 Journal. 6 pp., 15¢.

B600—Taste and Odor Control

AWWA B600-49T (formerly 5W1.70-T-1950)—**Tentative Standard Specifications for Powdered Activated Carbon.** Approved as Tentative July 11, 1949, and published in the February 1951 Journal. 14 pp., 20¢.

B700—Prophylaxis

AWWA B700-49—The Fluoridation of Public Water Supplies. A statement of recommended policy and procedure approved on May 29, 1949, and published in the July 1949 Journal. 5 pp., 15¢.

AWWA B701-50T (formerly 5W1.90-T-1950)—**Tentative Standard Specifications for Sodium Fluoride.** Approved as Tentative July 21, 1950, and published in the September 1950 Journal. 7 pp., 15¢.

C—Distribution

C100—Cast-Iron Pipe and Fittings

AWWA C100-08 (formerly 7C.1-1908)—**Standard Specifications for Cast-Iron Special Castings.** Originally approved May 12, 1908, as "Standard Specifications for Cast-Iron Water Pipes and Special Castings," the portion of this document dealing with pipe has been superseded by ASA A21.2-1939, which is listed below as AWWA C102-39. Until the American Standards Assn. Committee A21 completes A21.10, its pending specifications for cast-iron fittings, the AWWA 1908 document continues to be applicable to the purchase of special castings. 36 pp., 40¢.

AWWA C101-39* (ASA A21.1-1939)—American Recommended Practice Manual for the Computation of Strength and Thickness of Cast-Iron Pipe. Adopted by A.W.W.A. and the American Standards Assn. December 1939 and published in the December 1939 Journal. 81 pp., 50¢.

AWWA C102-39* (ASA A21.2-1939)—American Standard Specifications for Cast-Iron Pit-Cast Pipe for Water or Other Liquids. Adopted by A.W.W.A. and the American Standards Assn. December 1939 and published in the December 1939 Journal. 23 pp., 25¢.

AWWA C104-39* (ASA A21.4-1939)—American Standard Specifications for Cement-Mortar Lining for Cast-Iron Pipe and Fittings. Adopted by A.W.W.A. and the American Standards Assn. December 1939 and published in the December 1939 Journal. 9 pp., 20¢.

C200—Steel Pipe

AWWA C200-40T (formerly 7A.1-1940)—**Tentative Standard Specifications for Riveted Steel Pipe.** Published in the January 1940 Journal and made Tentative Apr. 25, 1940. 12 pp., 25¢.

AWWA C201-50 (formerly 7A.3-1950)—**Standard Specifications for Electric Fusion Welded Steel Water Pipe of Sizes 30 Inches and Over.** Published as Tentative in the January 1940 Journal and made Standard Apr. 25, 1940. Latest revision June 21, 1950. 20 pp., 25¢.

AWWA C202-49 (formerly 7A.4-1949)—**Standard Specifications for Steel Water Pipe of Sizes up to but Not Including 30 Inches.** Published as Tentative Revision of 1941 document in the April 1943 Journal. Made Standard Oct. 3, 1949. Latest revision June 21, 1950. 28 pp., 30¢.

* AWWA designations have been assigned mainly for indexing purposes. It is expected that the American Standards Association's "A21" designation will normally be used.

AWWA C203–51 (formerly 7A.5–1950)—**Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes 30 Inches and Over.** Published as Tentative in the January 1940 JOURNAL and made Standard Apr. 25, 1940. Latest revision May 1, 1951. 28 pp. (reprinted under same cover as AWWA C204–50, description of which follows).

AWWA C204–51 (formerly 7A.6–1950)—**Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes up to But not Including 30 Inches.** Published as Tentative in the January 1940 JOURNAL and made Standard Apr. 25, 1940. Latest revision May 1, 1951. 24 pp. (reprinted under same cover as AWWA C203–50), 45¢.

AWWA C205–41 (formerly 7A.7–1941)—**Standard Specifications for Cement-Mortar Protective Coating for Steel Water Pipe of Sizes 30 Inches and Over.** Published as Tentative in the January 1940 JOURNAL and made Standard June 26, 1941. *Revision pending.* 16 pp., 20¢.

AWWA C206–50T (formerly 7A.8–1950)—**Standard Specifications for Field Welding of Steel Water Pipe Joints.** Approved as Tentative Jan. 10, 1946, and published in the March 1946 JOURNAL. Made Standard Nov. 27, 1950. Latest revision Oct. 3, 1949. 12 pp., 20¢.

C300—Concrete Pipe

AWWA C300–47T (formerly 7B.1–T–1947)—**Tentative Standard Specifications for Reinforced Concrete Water Pipe—Steel Cylinder Type, Not Prestressed.** Approved as Tentative Dec. 11, 1947, and published in the March 1948 JOURNAL. 14 pp., 20¢.

AWWA C301–49T (formerly 7B.2–T–1949)—**Tentative Standard Specifications for Reinforced Concrete Water Pipe—Steel Cylinder Type, Prestressed.** Approved as Tentative Nov. 21, 1949, and published in the December 1949 JOURNAL. 16 pp., 20¢.

AWWA C302–51T—Tentative Standard Specifications for Reinforced Concrete Water Pipe—Noncylinder Type, Not Prestressed. Approved as Tentative Sept. 4, 1951, and published in the October 1951 JOURNAL. 15 pp., 20¢.

C500—Valves and Hydrants

AWWA C500–39 (formerly 7F.1–1939)—**Standard Specifications for Gate Valves for Ordinary Water Works Service.** Approved as Standard Apr. 28, 1938, and published in the March 1939 JOURNAL. 12 pp., 20¢.

AWWA C501–41T (formerly 7F.2–T–1941)—**Tentative Specifications for Sluice Gates.** Approved as Tentative June 26, 1941, and published in the October 1941 JOURNAL. 11 pp., 20¢.

AWWA C502–40 (formerly 7F.3–1940)—**Standard Specifications for Fire Hydrants for Ordinary Water Works Service.** Approved as Standard on January 17, 1940, and published in the August 1940 JOURNAL. 12 pp. (printed under same cover as C503–37, description of which follows), 20¢.

AWWA C503–37 (formerly 7F.3–1937)—**Standard Specifications for Uniform Marking of Fire Hydrants.** Published as Tentative in the April 1937 JOURNAL and made Standard June 7, 1937. (Printed under same cover as C502–40).

C600—Pipelaying

AWWA C600–49T (formerly 7D.1–T–1949)—**Tentative Standard Specifications for Installation of Cast-Iron Water Mains.** Revision of 1938 document approved as Tentative June 3, 1949, and published in the December 1949 JOURNAL. 33 pp., 35¢.

AWWA C601–48 (formerly 7D.2–1948)—**A Procedure for Disinfecting Water Mains.** Approved Sept. 30, 1947, and published in the February 1948 JOURNAL. Latest revision, Sept. 15, 1948. 8 pp., 15¢.

C700—Meters

AWWA C700–46 (formerly 7M.1–1946)—**Standard Specifications for Cold Water Meters—Displacement Type.** Published as Tentative in the December 1941 JOURNAL and made Standard May 10, 1946. 12 pp., 20¢.

AWWA C701–47 (formerly 7M.2–1947)—**Standard Specifications for Cold Water Meters—Current Type.** Published as Tentative in the April 1946 JOURNAL and made Standard July 25, 1947. 12 pp., 20¢.

AWWA C702-47 (formerly 7M.3-1947)—**Standard Specifications for Cold Water Meters—Compound Type.** Published as Tentative in the April 1946 JOURNAL and made Standard July 25, 1947. 11 pp., 20¢.

AWWA C703-49 (formerly 7M.4-1949)—**Standard Specifications for Cold Water Meters—Fire Service Type.** Published as Tentative in the February 1947 JOURNAL and made Standard Jan. 18, 1949. 12 pp., 20¢.

AWWA C704-50 (formerly 7M.5-1950)—**Standard Specifications for Cold Water Meters—Current Type—Propeller Driven.** Approved as Tentative July 21, 1949, and published in the August 1949 JOURNAL. Made Standard May 25, 1950. 12 pp., 20¢.

C800—Service Lines

AWWA C800-48 (formerly 7T.1-1948)—**Standard Specifications for Threads for Underground Service Line Fittings.** Approved as Tentative July 25, 1947, and published in the October 1947 JOURNAL. Made Standard Sept. 15, 1948. Included under same cover is "Collected Standard Specifications for Service Line Materials," a committee report. 15 pp., 25¢.

C900—Records and General

AWWA C900-40 (formerly 7G.1-1940)—**Recommended Practice for Distribution System Records.** Approved Jan. 16, 1940, and published in the February 1940 JOURNAL. Included under same cover are reprints of "Economies in Office Forms" by Israel Rafkind and "Coordinating Operating System Records With Accounting Records" by Nathan B. Jacobs. 52 pp., 45¢.

D—Storage

AWWA D100-48 (formerly 7H.1-1949)—**Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs.** Revision of 1941 document approved as Standard Sept. 20, 1948, and published in the April 1949 JOURNAL. 35 pp., 35¢.

AWWA D101-49T (formerly 7H.2-T-1949)—**Tentative Recommended Practice for Inspecting, Repairing and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs.** Revision of 1943 document approved as Tentative Sept. 20, 1948, and published in the October 1948 JOURNAL. Latest revision Sept. 28, 1949. 23 pp., 25¢.

Binder for A.W.W.A. Standards

A handy loose-leaf binder for A.W.W.A. standards has been prepared for bookshelf, desk and field use. Sturdily bound in blue canvas with backbone lettering in dark blue, the binder has metal hinges for maximum durability under all conditions. Capacious 1½-in. rings will hold more than a normal complement of specifications. Projecting tabs on eight blank separator cards insure prompt location of the user's choice of specifications groups. All specifications booklets are punched to fit the three rings of the binder. Price, $2.50, net.

Journal

AMERICAN WATER WORKS ASSOCIATION

VOLUME 43 • 1951

AMERICAN WATER WORKS ASSOCIATION
Incorporated
521 Fifth Ave., New York 17, N.Y.

Binding the Year's Journals

Through the cooperation of the Library Binding Institute, an organization of binderies which specializes in binding publications into volumes, arrangements have been made to give information and assistance to A.W.W.A. members who want to have their JOURNALS bound. This work may be done in accordance with standards of materials and construction required for durability, service and accessibility by college, reference and public libraries. The American Library Association and the Library Binding Institute have cooperated in promulgating "Minimum Specifications for Class A Library Binding" based on research and production and performance experience.

A committee of the American Library Association has certified responsible and reliable library binderies which have proved able to meet these specifications. To obtain standard quality binding, simply request Class A binding at any certified bindery. In obtaining price quotations, state the three dimensions of the volume.

Names and addresses of certified binderies in your area are available from the Library Binding Institute, 501 Fifth Avenue, New York 17, N.Y. Before sending copies to the bindery:

1. Check for missing issues and check each issue for defects, missing pages, etc. Be sure to include the volume index.
2. Tie the twelve issues together carefully so that nothing is crumpled or torn.
3. Write out definite instructions giving your preferences on the following points:
   a. Color of binding (one of the following standard colors should be selected: dark green, dark blue, black, brown or medium red).
   b. Whether the advertising sections and/or paper covers are to be bound into the volume.
   c. An exact copy of the text to be lettered in gold on the backbone. A common form is:

Journal—1¾ in. from top	Vol. 43—4¼ in. from bottom
A.W.W.A.—2¼ in. from top	1951—3¾ in. from bottom

   d. If you have had JOURNALS bound before and want your set to match as closely as possible, send a previous volume as a sample. If you want an approximate match, send a "rubbing" of the lettering on a previous volume and indicate the color.

If satisfactory arrangements cannot be made, or if there is any difficulty, advise the A.W.W.A. office and steps will be taken in cooperation with the Library Binding Institute to assure you proper service.

By arrangement with A.W.W.A., University Microfilms, 313 N. First St., Ann Arbor, Mich., is making a microfilm edition of the JOURNAL available to regular subscribers at a price comparable with the cost of library binding. The cost of the 1951 volume is tentatively expected to be \$6.75; the 1949 issues, comprising Vol. 41, are priced at \$6.25; those for 1950 (Vol. 42), at \$8.00.

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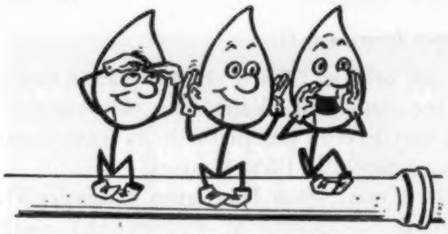


Percolation and Runoff

Card-carrying correspondents—not the Christmas card variety either —that's what they are, those undermentioned unmentionables who constitute the membership of Editors Anonymous. Only if you, yourself, are or ever have been a member will you be aware that this is the fourth anniversary of P&R, the perpetuation of which EA members not only advocate but effectuate. And only if you anted up your minimum of one contribution this year would you be aware that new membership cards have just been issued.

As the sub rosa nature of EAism would make it at least fatally inadvisable for any member not to stand on his constitutional rights—that is, for him to eat his card rather than show it—we have been able to reproduce here only this x-rayed facsimile of a sample ill-begotten by the late printer of same.

Percolation and Runoff
JOURNAL AMERICAN WATER WORKS ASSOCIATION
HEREBY CERTIFIES THAT

....

IS A MEMBER IN GOOD STANDING OF

EDITORS ANONYMOUS

FOR THE YEAR **1952**

AND IS ENTITLED TO THE ADMIRATION, OBEISANCE AND UNDYING DEVOTION OF WE, OURSELF,

GRADE OF MEMBER

....

Inasmuch as the grading schedule leaked out last anniversary, there's little secret now to the fact that one or two attacks of contributionitis per year make a *Jitter;* several, a *Shake;* many, a *Deetee;* and innumerable since the beginning, an *Incurable*. What remains a secret yet is the 1951 attack list; and only because we've promised to "preserve" their anonymity need we remind ourself below who "they" are:

(*Continued on page 2*)

(*Continued from page 1*)

Incurables incorrigible are the original "Three PinkelephantEArs"; P. S. Wilson, Inc.; E. L. Filby, Inc.; and J. M. Wafer, Inc. Having wet-nursed P&R through its infancy, they haven't deserted it in its infantilism. More than P&Rdiatricians, these—practically P&Rpetrators.

Deetees determined have been a new "Four EArsemen"; Charles H. Capen, D.T.; Raymond L. Jones, D.T.; Thomas M. Riddick, D.T.; and George E. Symons, D.T. All these have cut, clipped and commandeered cataleptically to provide fuel for P&R's furnace.

Shakes alive and only a snip away from earning their degrees are John M. Diven, W. Victor Weir, Donald B. Williams and E. A. Sigworth, the last of whom undoubtedly uses those initials rather than a name for their P&R significance. These four have already done well in agitation and promise much more.

And *Jitters* all over the place to keep P&R hopping—sometimes with whimsy aforethought, sometimes not, but always with welcome grist: William W. Aultman, W. N. Beadle, A. P. Black, James D. Brown, H. Trendley Dean, N. M. DeJarnette, C. F. Drake, Rolf Eliassen, George G. Fassnacht, George E. Ferguson, L. A. Jackson, Henry J. Ongerth, Thomas B. Robinson, Alonza Shinn, Arthur B. Spaulding, Ralph L. Tyler and W. A. Welch.

Altogether, 28 where last year there were only 17—even A.W.W.A. can't match that growth. Is it any wonder then that we're Merry Christmasing like all getout and that we're scarcely willing to wait for what we know will be a Happy New Year even fuller of anonymouses and their wonderful anonymosity.

Fluoridation rides again in San Francisco, and this time it's really riding high, on the crest of an almost 2 to 1 support by the voters in the November election. Last spring, as you may remember, the first steps toward addition of fluorides to the water supply had already been taken, following city council approval of the procedure, when strong protests, particularly by Christian Scientists, forced the council to reverse itself and plan this first referendum ever on the question. The campaign that followed was not a quiet one, but the Citizens' Committee for Fluoridation prevailed over the Citizens' Committee for Preservation of San Francisco's Good Water, apparently convincing a large majority of the voters that fluoridation was neither "mass medication" nor "unsound economics."

Meanwhile, in a rapidly growing number of communities—now well over 100—fluoridation is being practiced and in hundreds more is being discussed, argued over or fought for. All of which has led the American Dental Association to predict that, within a year, one of every five Americans will be drinking water containing adequate fluorides. And you can put that in your pipes or provoke it!

(*Continued on page 4*)

(Continued from page 2)

The heart of Texas must have sprung a leak. At any rate, when the mayor of "deep in" El Paso had a friendly chat with his constituents the other day, practically the whole country was eavesdropping. Secret of the listening was not—unfortunately—the fact that the mayor's subject was water supply problems, but a misconnection which put the speech on 182 national, rather than the five local radio stations. The Californian who finally phoned in a report of the erroneous hookup was apparently much more concerned about a mix-up with his scheduled soap opera than the $11,000,000 water supply bond issue involved. Probably troubled with suds!

Newton's fig has outlasted his apple. At any rate, gravity appears to be tottering on the brink of obsolescence. Not just space ships and interplanetary flights, not just ultraspheric observation stations and flying saucers, now the San Diego water department has jumped on the defiance wagon and decided to pump water downhill. By so doing, with three 200-hp. centrifugal pumps, the department will boost flow in its overtaxed system from 45 to 55 mgd. All well and good, but, if we don't watch out, all this science-defiance is going to blow us back to an earlier apple and a fig leaf instead of a fig. So what, we suppose—with all that milk and honey, who'll want water?

(Continued on page 6)

(*Continued from page 4*)

Model in every sense of the word is the recent reproduction of the two-square-block Croton Reservoir that, 50 years ago, made Fifth Avenue and 42nd Street in New York City a favorite Sunday strolling place. Built on a 1 : 100 scale, the model is being displayed in the lobby of the New York Public Library, which now occupies the site of the reservoir. But even modeler, old Croton is now fast filling with coins, pitched into it by contributors to the library's third drive for public funds. Who wouldn't want a reservoir like that, on any scale?

Really remarkable to us, though, is the fact that this is the second of its three appeals to date which the library has keyed to water supply, the earlier one having been a tie-in with the city's water shortage. The new drive, of course, may merely be considered a means to capitalize on the public's passion for throwing its money away—literally, here, rather than literately. But who'd have thunk that water supply, in any sense, could be picked by any one as a good money maker?

Money-maker or not, though, water supply continues to make good copy. Scarcely a day passes any more that some writer, reporter or advertising agent doesn't call A.W.W.A. for information on some aspect of the subject. And what has been most gratifying has been the very sharp decline in the percentage of frightwriting found in current water stories. Even in discussing water shortage or water contamination these days, our lay experts don't lay it on quite as thick. And some sensationalists have even discovered that water supply facts often outstrange their imaginations.

In the Richmond, Va., *Times-Dispatch,* last month, a Sunday feature on drought not only reported the facts on water shortage but indicated the avoidable reasons why some people suffer from it. In the Atlanta *Journal,* meanwhile, an editorial on flood and drought spent more space recording good conservation practices than it did in predicting the calamities that would result if they weren't employed. Similarly, the New York City newspapers did a remarkably subdued, though still prominent, job of reporting the activation of a fleet of 24 jeep patrol wagons and 2 mobile laboratories for 24-hour armed protection of the city's Catskill water supply system. And such discoveries as the fact that the new U.S. Steel plant at Morrisville, Pa., will use about 70 per cent as much water as did all of Philadelphia in 1950 have been good for good feature articles, and more and more often too. Finally, to make a good press even better, there have been more and more popular magazine articles on everything from fluoridation to fire water, plus such tidbits as the revelation by Octavus Roy Cohen in *This Week* that the happiest person he ever met was an old lady in Death Valley who finally owned her own well, to add human interest to the water word.

But harking back to that "money-making," what better than a good press to promote it?

(*Continued on page 8*)

(*Continued from page 6*)

Harry A. Faber, research chemist for the Chlorine Institute since 1935, has accepted the post of full-time associate editor for the publication *Water & Sewage Works,* effective January 1, 1952. A well known student of chlorine technology, he is responsible for many advances in the art of water treatment and his name has appeared frequently in the programs for water and sewage works meetings, as well as in the contents pages of technical publications. Among the editorial projects in which he has had a hand are the books *Elements of Sanitation* and *Water Quality and Treatment,* and the projected revision of *Standard Methods.* He received A.W.W.A.'s Diven Medal in 1948 and shared its Goodell Prize in 1949.

Radiological health training will be furnished to qualified applicants through short courses to be conducted by the Public Health Service at its Environmental Health Center, Cincinnati, Ohio. There is no tuition, but the program is designed for professional people primarily concerned with radiological health problems in their respective fields, and candidates should have a degree in engineering, physical or biological science, or medicine, and should have experience in work relating to public health.

Basic course provides two weeks of orientation in the fundamental theory of radiation and radiation-detecting instruments, the use and maintenance of such instruments, the permissible level of radiation dosage and effects of exceeding it, and shielding and protective measures which may be taken. Three basic two-week courses are scheduled, beginning January 21, March 10 and April 21, 1952.

Intermediate courses, designed for those who have completed the basic course or its equivalent, provide two weeks' training in the operation, maintenance and repair of radiation detection devices used for the monitoring of both personal and water, food and other samples. These courses are scheduled for the two-week periods beginning February 4 and May 5, 1952.

Additional information on the curriculum and application procedure may be obtained from the Chief, Radiological Health Training Section, Environmental Health Center, 1014 Broadway, Cincinnati 2, Ohio.

Water pollution control engineers are still required by California's pollution control program, created by legislation in 1949, and applications will be accepted until March 15, 1952. Further information may be obtained from the California State Personnel Board, 1015 L St., Sacramento.

Edward A. Phoenix has been appointed to the newly created post of manager of the Market Surveys Dept., Johns-Manville Corp. Formerly assistant manager of the Transite Pipe Dept., Phoenix will now work on the market development of all the company's products.

(*Continued on page 10*)

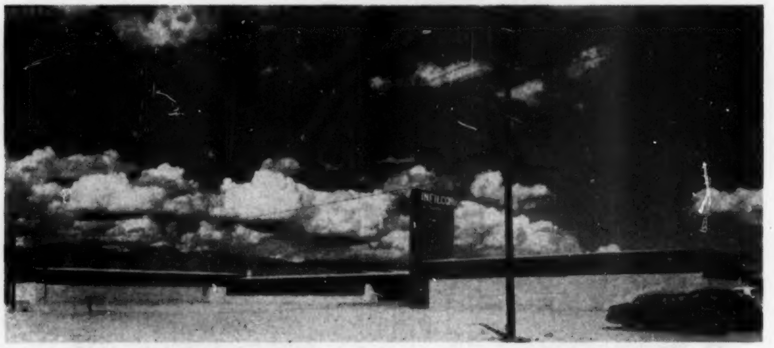
(Continued from page 8)

A thousand-arm grasp on that Old Oaken Bucket makes the California Section's possession of the trophy, annually awarded to A.W.W.A.'s largest section, difficult to dispute. Greeting the one-thousandth member of the section is William W. Hurlbut, Los Angeles consultant, Past-President of A.W.W.A. and chairman of the section's Membership Committee (right). Member No. 1,000 (left) is Maurice Silman of the Palm Springs Outpost Water Co., Palm Springs. In California water has long been king—king now with a thousand princes.

Photo courtesy Western City

(Continued on page 12)

(*Continued from page 10*)

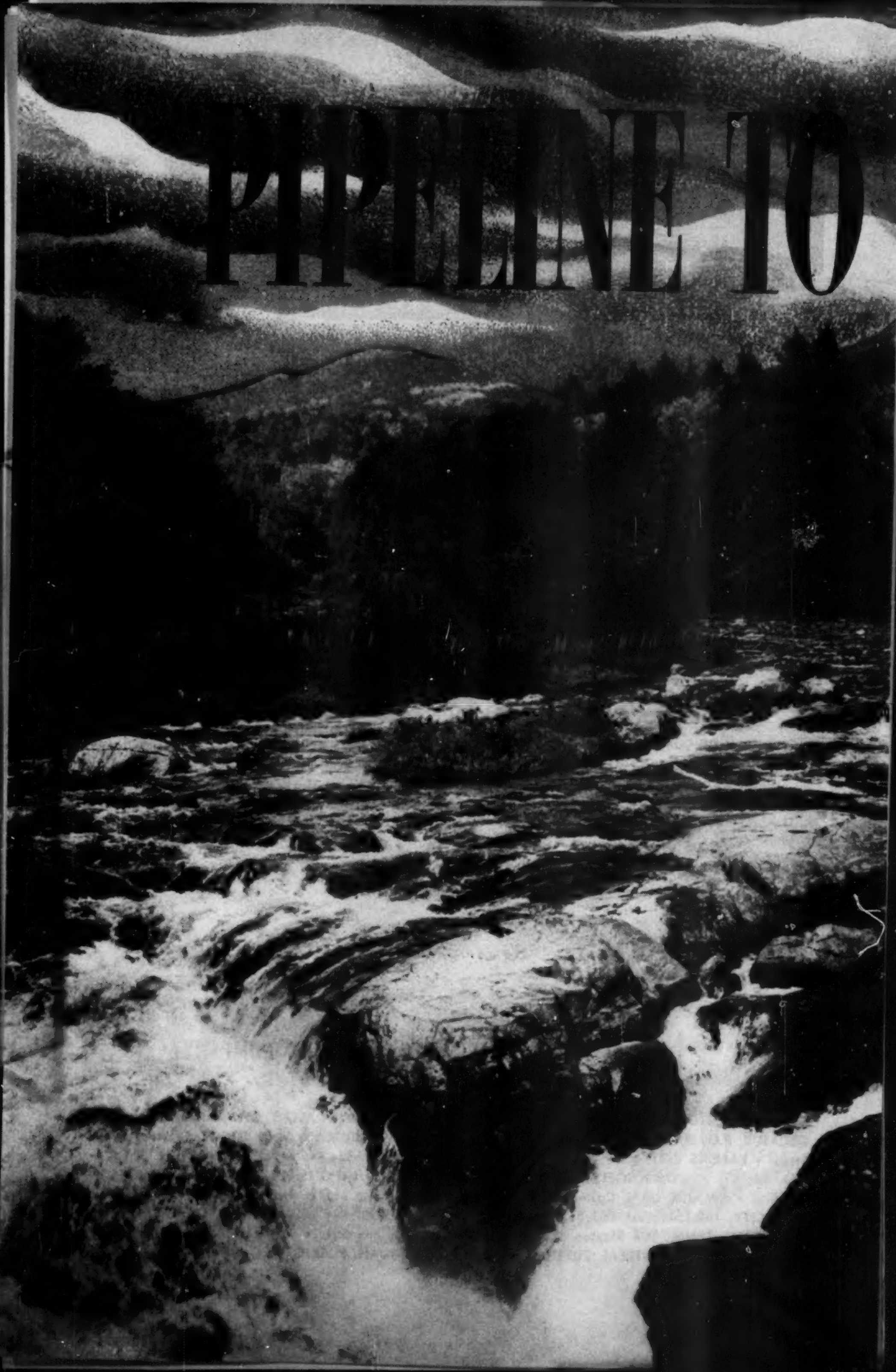


The newly completed research and executive headquarters building of Infilco, Inc., at Tucson, Ariz., includes 40,000 sq.ft. of floor space and houses the company's engineering, research and development divisions, as well as the home sales and executive offices.

A hydraulic calculator has been designed to determine head loss, flow, velocity, pipe size and 1.85 $\frac{h}{Q}$ factor. The calculator, made like a circular slide rule with plastic disks and indicator arm, has a diameter of 6 in. Calibrations are based on the Hazen-Williams formula and are sufficient to cover a range of pipe sizes from 4 to 72 in. The calculator may be obtained from Robert E. Martin, 210 Heyburn Bldg., Louisville, Ky., at a cost of $6.00.

H. B. Foote has retired as director of sanitary engineering for the Montana Board of Health on October 25, after 28 years in that post and a total of 34 years with the board. An active participant in technical and professional organizations, he has been active in the Montana Section, in which he held several offices, and received its Fuller Award in 1942.

(*Continued on page 16*)


PIPELINE TO

(Continued from page 12)

Three of a kind, who were honored on October 19 by the Northern Illinois Waterworks Institute and the Northwestern University Centennial Committee as outstanding water works men, are, left to right, A.W.W.A. Secretary Harry E. Jordan, Chicago City Engineer W. W. DeBerard, and Chicago Engineer of Water Purification John R. Baylis. In addition to the citation certificates, the special centennial medallions, the glasses and the "swallowed canary" expressions, all three are also of a kind in being Honorary Members of A.W.W.A.

Mark D. Hollis, chief engineer officer of the Public Health Service, has been promoted to a grade corresponding to major general. As assistant bureau chief and assistant surgeon general, he has directed the environmental health and engineering activities of U.S.P.H.S. since January 1948, and played an active rôle in developing the Environmental Health Center at Cincinnati and the Ohio River pollution survey.

An unfortunate result of the recent Southwest Section meeting was an injury suffered by Lloyd C. Billings, supervisor and chief chemist of purification at Dallas, Tex. On October 16, while showing some meeting-goers through the Carrollton plant, which is under construction, he suffered a 10-ft. fall into a concrete flume, fracturing a leg and a vertebra. At last report he was making satisfactory progress toward full recovery.

(Continued on page 20)

STAMINA!*

* First run in England 112 years ago, the Grand National Steeplechase, over the famous Aintree course of 4 miles, 856 yards, was won in the record time of 9.20-2/5 by Golden Miller in 1934.

CAST IRON ®

CAST IRON PIPE RESEARCH ASSN., THOS. F. WOLFE, MANAGING DIRECTOR, 122 SO. MICHIGAN AVE., CHICAGO 3.

SERVES FOR CENTURIES

(Continued from page 16)

John P. Harris is retiring as Chicago district manager of the Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., after a quarter of century of marketing the company's products. A pioneer in the development of activated carbon as a water purification agent, he introduced it in Chicago a quarter of a century ago, when he was a jobber there. Among the men whom he supplied and with whom he worked are John Baylis, who carried out some of the first practical tests of the material at Chicago, and Charles Spaulding of Springfield, Ill., who developed the threshold odor test. Before becoming interested in water purification, he had worked as a chemist and industrial manager in refining operations on fatty oils. After his retirement, he will operate his own chemical sales business at 1791 Howard St., Chicago. He is succeeded as Chicago district manager of the division by John F. Zieserl, formerly administrative assistant to the vice-president in charge of chemical sales.

(Continued on page 58)

Correspondence

That Third "R"

To the Editor:

Your dissertation in the October P&R section (p. 12) upsets my mathematics. I have always understood that 86 proof Scotch contained 43 per cent alcohol. If only 14 per cent of the contents of the bottle is water, what is the other 43 per cent?

W. Victor Weir

Pres. & Gen. Mgr.
St. Louis County Water Co.
University City, Mo.; Nov. 5, 1951

To the Editor:

Your effusion on the mounting tax burden borne by water somewhat diluted with Scotch was quite appropriate to these times when even Milwaukee has found it necessary to erase the nickel beer.

Unfortunately, your sad story is the more lamentable because your arithmetic was faulty and your knowledge of the alcoholic contents of usquebaugh wholly unsound. This caused you to err by nearly an order of magnitude in assessing the effect of taxation on the cost of a flagon of the national libation of our Caledonian friends (who can no longer afford to partake of it).

A proof gallon of whiskey contains 57.06 per cent of ethyl alcohol by volume. Scotch, being customarily 86 proof, thus contains 49.07 per cent of alcohol. But this information is not necessary to figure the cost of dilution water, which is, simply, $\$10.50 \times 0.86$

(*Continued on page 78*)

Membership Changes

NEW MEMBERS

Applications received October 1 to October 31, 1951

Baker, R. H., Designing Engr., Smith-Blair Inc., 535 Railroad Ave., S., San Francisco, Calif. (Oct. '51) *MR*

Beverly Water Dept., Roger F. Duwart, Comr. of Public Works, City Hall, 191 Cabot St., Beverly, Mass. (Mun. Sv. Sub. Oct. '51) *MPR*

Birchall, Arthur J., Resident Engr., Smith & Gillespie, 214 E. 4th St., Panama City, Fla. (Oct. '50)

Bishton, Albert H., Sr. Eng. Draftsman, Water Div., District of Columbia Government, 14th & E Sts., N.W., Washington 4, D.C. (Oct. '51)

Blumer, F. L., Supt. of Production, Water Dept., City Hall, Lincoln 8, Neb. (Oct. '51) *PR*

Brazie, James B., Water Supt., Calexico, Calif. (Oct. '51) *MP*

Briggs, Chauncey Millar, Sr. Filtration Engr., 220 S. State, Chicago, Ill. (Oct. '50) *PR*

Bruggeman, R. W., *see* Chanute (Kan.)

Buffalo Pipe & Foundary Corp., Keyran J. Hooley, Sales Repr., Box 55, Station B, Buffalo 7, N.Y. (Assoc. M. Oct. '51)

Burger, Clarence W., Jr., Chief Eng. Draftsman, Water Dept., District of Columbia Government, 14th & Pennsylvania Ave., N.W., Washington, D.C. (Oct. '51)

Carmichael, Jess J., Supt. of Utilities, Munic. Power Plant, Slater, Mo. (Oct. '51) *MP*

Caruthers, Claude S., Asst. Mgr., Smith Machinery Co. of Texas, Box 836, Pecos, Tex. (Oct. '51) *MPR*

Chabot, Alfred T., Attorney-at-Law, American Water Works Service Co., 121 S. Broad St., Philadelphia 7, Pa. (Oct. '51) *M*

Chanute, City of, R. W. Bruggeman, City Engr., Chanute, Kan. (Corp. M. Oct. '51)

Chapman, John W., Supt. of Munic. Water Works, Hurricane, W.Va. (Oct. '51) *MP*

Chisholm, William D., Production Reprs., Pacific Coast Coca-Cola Bottling Co., Box 50, Richmond Beach, Wash. (Oct. '51) *P*

Christian, A. M., Salesman, Fisher Scientific Co., 133 Oliver, Franklin, Ind. (Oct. '51)

Cohen, Akiva, c/o Haim Cohen, Ramat Gan, Israel (Oct. '51) *MR*

Corden, Bernard, Asst. Utilities Engr., Hydraulics Div., California Public Utilities Com., 368 State Bldg., San Francisco 2, Calif. (Oct. '51)

Crew, Alfred, Cons. Engr., 154 Linden St., Ridgewood, N.J. (Oct. '51)

Culbertson, Thomas M., Hydrologist, Pecos County Water Improvement Dist. No. 1, Box 896, Fort Stockton, Tex. (Affil. M. Oct. '51) *R*

Cypert, Roy P., San. Engr., State Health Dept., Austin, Tex. (Oct. '51)

Davison, Russell, Supt., Water & Sewer Dept., Box 103, Platteville, Wis. (Oct. '51) *MP*

Dreyfus, Woods O., Salesman, Badger Meter Mfg. Co., Milwaukee 45, Wis. (Oct. '51)

Dubek, Clifforf, *see* Johnson & Johnson

Duwart, Roger F., *see* Beverly (Mass.) Water Dept.

Dyer Municipal Water Utility, Clifford W. Giese, Supt., 226 Schulte St., Dyer, Ind. (Corp. M. Oct. '51) *M*

Edington, W. J., City Engr., Moncton, N.B. (Oct. '51)

Engineering Service Corp., Edwin W. Wicht, Public Relations, 1127 W. Washington Blvd., Los Angeles 15, Calif. (Corp. M. Oct. '51) *MPR*

(*Continued on page 32*)

(*Continued from page 30*)

English, E. Rowland, Vice-Pres., Pipe Protection Service, Inc., 10 Center St., Elizabeth, N.J. (Oct. '51) *M*

Ferris, T. C., Dist. Engr., State Health Dept., E. 5th St., Austin, Tex. (Oct. '51)

Gennis, Ivan Frederick, Asst. San. Engr., State Dept. of Public Health, 2180 Milvia St., Berkeley, Calif. (Oct. '51)

George, Jesse E., Supt. of Utilities, Box 163, Palmyra, Mo. (Oct. '51) *MPR*

Giese, Clifford W., *see* Dyer (Ind.) Municipal Water Utility

Halley, Edward M., Eng. Aide, Water Div., District of Columbia Government, 14th & E Sts., N.W., Washington 4, D.C. (Oct. '51)

Hanger, David, Water Works Supt., Morocco, Ind. (Oct. '51)

Hissam, Donald Lester, Supt. of Water Works, Chester, W.Va. (Oct. '51) *M*

Holdsworth, H. J., *see* Parsons Co., The

Hooley, Keyran J., *see* Buffalo Pipe & Foundry Corp.

Hornung, James, San. Chemist, Dept. of Water Supply, Detroit, Mich. (Oct. '51) *P*

Holloway, H. F., Mgr., Midland Water Co., 10th St. & Railroad Lane, Midland, Pa. (Oct. '51) *MPR*

Hotchkiss, Glenn R., Engr., Sales Dept., The Layne-Texas Co., Ltd., Box 9098, Houston 11, Tex. (Oct. '51) *R*

Johnson & Johnson, Clifford Doubek, Chem. Engr., 4949 W. 65th St., Chicago 38, Ill. (Corp. M. Oct. '51) *P*

Kabler, Paul W., Chief, Bacteriology Section, Environmental Health Center, Public Health Service, 1014 Broadway, Cincinnati, Ohio (Oct. '51) *P*

Keithley, Mills J., *see* New Holstein (Wis.)

Kells, Gordon King, Sales Repr., Neptune Meter Co., 320 Market St., San Francisco 11, Calif. (Oct. '51)

Kieffer, Charles James, Comr., East Jefferson Water Works Dist. No. 1, 700 Labarre St., Jefferson, La. (Oct. '51)

King, Donald A., Sales Repr., Pennsylvania Salt Mfg. Co., 2328 Buhl Bldg., Detroit 26, Mich. (Oct. '51) *P*

Leffel, R. Ernest, Asst. Prof., Civ. Eng., Univ. of Colorado, Boulder, Colo. (Oct. '51) *MPR*

Lorah, John C., Supt., Light & Water Dept., Sycamore, Ohio (Oct. '51) *M*

Lyman, Ross C., Owner-Mgr., Servisoft Soft Water Service, 109 E. Clark St., Champaign, Ill. (Oct. '51)

MacDonald, Edmund Leslie, Mgr., Mokelumne Div., East Bay Munic. Utility Dist., 512—16th St., Oakland, Calif. (Oct. '51) *M*

Malone, Clarence L., Water Supt., Hughes Springs, Tex. (Oct. '51) *M*

Mann, John F., Jr., Asst. Prof., Dept. of Geology, Univ. of Southern California, Los Angeles 7, Calif. (Oct. '51) *R*

Martin, Miles Herbert, Supt., West Virginia Water Service Co., Oak Hill, W.Va. (Oct. '51) *MP*

Matthias, Paul H., Eng. Aide, District of Columbia Water Div., District Bldg., Washington, D.C. (Oct. '51) *M*

McCamant, Donald G., Vice-Pres. & Gen. Mgr., Hutchinson Water Co., Inc., Box 148, Hutchinson, Kan. (Oct. '51) *MPR*

McCune, Franklin A., Supt., Water Works, 209 N. Water St., New Bremen, Ohio (Oct. '51)

(*Continued on page 34*)

(*Continued from page 32*)

McMullen, William L., Sr., Owner & Mgr., Western Auto Associate Store, Brookhaven, Miss. (Oct. '51) *M*

Miller, Theodore M., Office Mgr., Columbia Water Co., 220 Locust St., Columbia. Pa. (Oct. '51) *MP*

Milwaukee Lead Works, Lawrence N. Schmitt, Pres., 3139 N. 31st St., Milwaukee 16, Wis. (Assoc. M. Oct. '51)

Mitchell, James R., Assoc. Engr., District of Columbia Water Div., 133 Hamilton St., N.W., Washington 11, D.C. (Oct. '51)

Moriarty, Lawrence Robert, San. Engr., State Board of Health, 205 Harrison St., La Porte, Ind. (Oct. '51) *MPR*

New Holstein Public Utility, Mills J. Keithley, Supt., Water Dept., 1819 Park Ave., New Holstein, Wis. (Corp. M. Oct. '51) *M*

Norris, Donald C., Sales Engr., Johns-Manville Sales Corp., 1220 Madison Ave., Toledo 2, Ohio (Oct. '51)

Olsson, John Edward, Jr. Engr., Fulton & Cramer, 922 Trust Bldg., Lincoln, Neb. (Oct. '51) *MPR*

Omachi, Henry T., Graduate Student, Univ. of Minnesota, 926 Washington Ave., S.E., Minneapolis 14, Minn. (Jr. M. Oct. '51)

Parsons Co., The, H. J. Holdsworth, Vice-Pres. & Gen. Mgr., 200 N. 8th Ave. E., Newton, Iowa (Assoc. M. Oct. '51)

Pennington-Winter Water Systems, Inc., Frank J. Winter, Vice-Pres., 2911 Apco Tower, Oklahoma City, Okla. (Assoc. M. Oct. '51)

Pierce, William M., Jr., Owner, Ayle Water Works, 3308 N. Main St., Fort Worth, Tex. (Oct. '51) *M*

Pipe Linings, Inc., Robert C. Sargent, Exec. Vice-Pres. & Gen. Mgr., 4675 Firestone Blvd., South Gate, Calif. (Assoc. M. Oct. '51)

Ragan, Richard Walton, Bureau of San. Eng., State Board of Health, 1763 Mayfair Village, Jacksonville, Fla. (Oct. '51)

Rauch, Oswine E., Safety Service Director, City Hall, Fremont, Ohio (Oct. '51)

Rodgers, Wyatt A., Operator, Water Plant, Jacksboro, Tex. (Oct. '51)

(*Continued on page 36*)

(*Continued from page 34*)

Ryan, M. F., *see* Sheridan (Wyo.)

Sargent, Robert C., *see* Pipe Linings, Inc.

Schaefer, Leslie G., Eng. Draftsman, Water Div., District of Columbia Government, 14th & E Sts., N.W., Washington 4, D.C. (Oct. '51)

Schmitt, Lawrence N., *see* Milwaukee Lead Works

Serrin, Joseph Edward, Asst. Engr., Water Div., District Bldg., 14th & Pennsylvania Ave., N.W., Washington, D.C. (Oct. '51) *M*

Sheffield, L. B., Mgr., Water Works Board, Ozark, Ala. (Oct. '51) *M*

Sheridan, City of, M. F. Ryan, City Clerk, Sheridan, Wyo. (Corp. M. Oct. '51) *MPR*

Smith, Byron C., Dist. Supt., Southern California Water Co., 4461 W. Lennox Blvd., Lennox, Calif. (Oct. '51) *MPR*

Smith, Sidney D., Supt., Tech. Section, E. I. du Pont de Nemours & Co., Box 993, Charleston, W.Va. (Apr. '51) *MP*

Spicer, Louis Mason, Jr., Lab. Supervisor, Calco Chem. Div., American Cyanamid Co., Piney River, Va. (Oct. '51) *PR*

Sprowles, Lincoln, Supt. of Utilities, Board of Public Affairs, Plymouth, Ohio (Oct. '51) *M*

Sturgill, Ray, Service Engr., Simplex Valve & Meter Co., 1408 Independence Bldg., Charlotte, N.C. (Oct. '51)

Sutter, Fred, Owner, Sutter Well Works, Box 156, Pass Christian, Miss. (Oct. '51) *R*

Swartz, Warren, Supt., Water Dept., Elkhart, Ind. (Oct. '51) *M*

Taber, Douglass, Dist. Sales Mgr., Builders-Providence, Inc., 404 Frick Bldg., Pittsburgh, Pa. (Oct. '51) *P*

Thacker, Richard Lathrop, Owner, Thacker Eng. Office, 226 Washington St., Waukegan, Ill. (Oct. '51) *PR*

Thompson, Robert Howard, Plant Supt., Munic. Water Works, 314 N. 4th St., Burlington, Iowa (Oct. '51) *P*

Thornett, Howard D., Asst. Constr. Engr., District of Columbia Water Div., District Bldg., 14th & E Sts., N.W. Washington 4, D.C. (Oct. '51) *M*

Thurman, Farris D., Water Plant Supt., 725 N. Church St., Fayette, Mo. (Oct. '51) *MPR*

Tylar, George, Eng. Aide, Water Div., District of Columbia Government, 14th & E Sts., N.W., Washington 4, D.C. (Oct. '51)

Wainer, Richard, Civ. Eng. Asst., Dept. of Water & Power, Box 3669 Terminal Annex, Los Angeles 54, Calif. (Oct. '51) *M*

Weiss, Kenneth H., City Clerk & Mgr. of Water Dept., 100 N. 6th Ave., West Bend, Wis. (Oct. '51) *M*

Wicht, Edwin W., *see* Engineering Service Corp.

Winter, Frank J., *see* Pennington-Winter Water Systems, Inc.

Young, Ethel Goodwin, (Mrs.), Secy. to Director of Public Utilities Dept., Box 366, Raleigh, N.C. (Affil. M. Oct. '51) *M*

Zielbauer, Edward J., Geologist, Los Angeles County Flood Control Dist., 751 S. Figueroa St., Los Angeles 17, Calif. (Oct. '51) *R*

REINSTATEMENTS

Border, W. R., Supt., City Water Works, Bozeman, Mont. (Apr. '47)

Carroll, John T., Asst. Dist. Mgr., Worthington Pump & Machinery Corp., 400 W. Madison St., Chicago 6, Ill. (July '25)

Craun, Bernard T., San. Engr., State Dept. of Health, Phoenix, Ariz. (July '49)

Day, Kenneth A., Supt. of Filtration, Board of Water Comrs., City & County Bldg., Box 629, Denver, Colo. (Apr. '47)

Erwin, Raymond A., Power Div., Dept. of Water & Power, 12000 Otsego St., North Hollywood, Calif. (Jan. '47)

Fitch, Reamy C., Cons. Engr., 650 N. 1st Ave., Phoenix, Ariz. (July '47) *MPR*

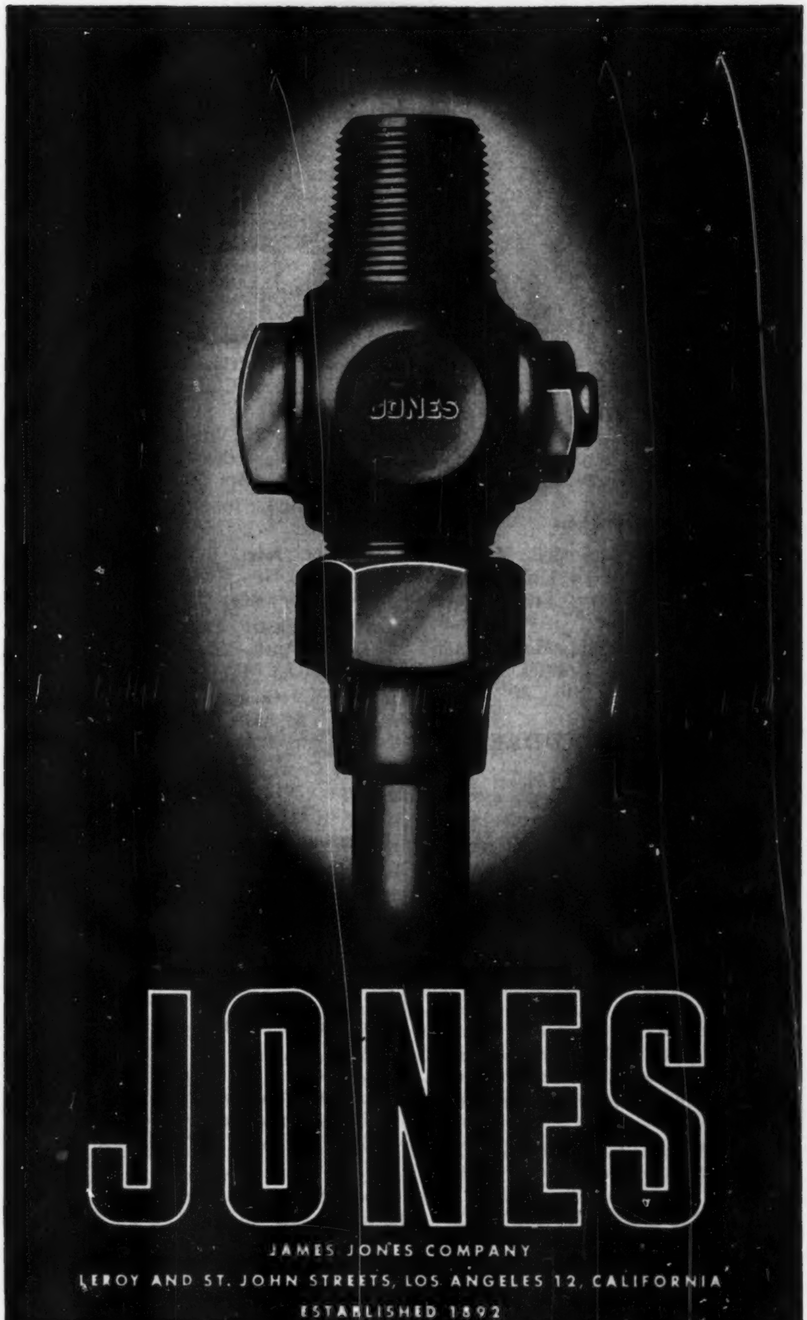
Parratt, S. L., Dist. Engr., Aqueduct Div., Dept. of Water & Power, Box 147, Independence, Calif. (Oct. '31) *MR*

Reading Bureau of Water, 207 City Hall, Reading, Pa. (Corp. M. Mar. '16)

Seevers, Harry V., Salesman, Mueller Co., 310 Walnut St., Ottawa, Kan. (Jan. '48)

Wall, James S., Supt., Water Works, Box 234, Huntsville, Ala. (Apr. '38)

(*Continued on page 38*)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(*Continued from page 36*)

LOSSES

Deaths

Booth, George W., R.D., Glen Gardner, N.J. (Feb. '24) *Honorary M. '45. R*

Bradley, Joseph F., Chief Engr., Dept. of Water Works, 201 Lincoln Way, Valparaiso, Ind. (Feb. '21)

Burhorst, Raymond F., Sr. Eng. Aide, Bureau of Water Supply, 2009 E. Lanvale St., Baltimore 13, Md. (Jr. M. Jan. '50) *M*

Hall, Lisle G., Mgr., The Terre Haute Water Works Corp., 119 S. 7th St., Terre Haute, Ind. (July '48) *M*

Hawkins, Ralph, Water Comr., Box 7, Auburn, Neb. (July '46)

Reinheimer, J. P., Supt., Water Dept., Springfield, Ohio (July '46) *MR*

Resignations

VanDusen, Dana, Vice Gen. Mgr.-Gen. Counsel, Metropolitan Utilities Dist., Utilities Bldg., Harney St., Omaha 2, Neb. (Jan. '44) *M*

Waterloo Water & Light Com., Edmund R. Wagner, Supt. of Utilities, Waterloo, Wis. (Corp. M. Apr. '49) *M*

CHANGES IN ADDRESS

Changes received between October 5 and November 5, 1951

Albert Lea Water Dept., R. L. Van Nocker, City Mgr., Albert Lea, Minn. (Corp. M. Oct. '40)

Alexander Chemical Corp., Alexander B. Maley, Pres., 3604 S. Morgan St., Chicago 9, Ill. (Assoc. M. Jan. '50)

Allan, L. B., *see* Toronto (Ont.) Dept. of Works

Allen, E. L., Sr., Resident Engr., Robert & Co., Inc., 411 E. Amelia Ave., Orlando, Fla. (Oct. '49)

Bannen, John, Box 243, Hurricane, W.Va. (July '44) *P*

Bengel, William C., Designing Engr., Brown & Root Constr. Co., 6435 W. Chester, Houston, Tex. (Jan. '50) *MPR*

Beyer, Walter R., Chief Purchasing Agent, Florida State Univ., Tallahassee, Fla. (Jan. '44) *M*

Burns, Robert E., The Permutit Co. of Canada, Ltd., 137 Wellington St., W., Toronto, Ont. (July '51) *P*

Burzell, L. R., *see* Vista (Calif.) Irrigation Dist.

Carnahan, R. D., R.F.D. 2, Leesburg, Fla. (Jan. '47) *P*

Carroll, Thomas M., Mgr., Water Well Drillers Assn. of Southern California, 5567 N. Rosemead Blvd., Temple City, Calif. (July '49)

Case Ray, City Mgr., Greeley, Colo. (Apr. '48) *Director '50–'53.*

Chillicothe Municipal Utilities, Morris B. Willis, Mgr., Chillicothe, Mo. (Corp. M. July '42)

Clark, Robert N., World Health Organization, Palais des Nations, Geneva, Switzerland (Apr. '47)

Cox, Rupert L., 1664 Boyce Dr., Norfolk, Va. (Oct. '47) *MP*

Davidson, John, John Davidson, Ltd., 1606 W. 5th Ave., Vancouver, B.C. (Apr. '46) *M*

de Paiva Castro, Paulo, Engr., 428 Rua Piaui, Apto. 66, Sao Paulo, S.P., Brazil (Oct. '45)

Erganian, George, Engr., Henry B. Steeg & Assocs., 1555 E. 52nd St., Indianapolis 5, Ind. (Apr. '46) *MP*

Faust, George K., City Engr. & Water Supt., 2912 Broadway, Parsons, Kan. (Apr. '49)

Ferguson, George E., Water Resources Div., U.S. Geological Survey, 2228 General Services Administration Bldg., Washington 25, D.C. (July '41) *Director '46–'48. Fuller Award '48. R*

Ford, H. W., Pittsburgh-Des Moines Steel Co., 1060 Broad St., Newark 2, N.J. (July '35) *R*

Fort Dodge Water Dept., Quentin J. Wildman, Asst. Mgr., Fort Dodge, Iowa (Corp. M. Jan. '43)

Gannon, Timothy J., 3526 San Pablo Lane, Santa Barbara, Calif. (July '49)

Garrett, Melrose T., Jr., 5008 Almeda, Houston 4, Tex. (Jr. M. Jan. '51)

Gearhart, John B., Box 534, Coquille, Ore. (Apr. '48)

Girand, James, Vice-Pres., New York Water Service Corp., 132 W. 43rd St., New York 18, N.Y. (Jan. '49)

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Granda y Deben, Robel, 701 Esq. a 29, Apdo. 6, Vedado, Havana, Cuba (July '38) *MPR*

Hagar, Major C., City Mgr., Sterling, Kan. (Apr. '39) *Director '49–'52.*

Hoffman, L. J., Sr. Assoc. Engr., Water Works, 565 Johnston St., Akron 11, Ohio (Apr. '39) *Fuller Award '47. M*

Holmgren, Richard S., Jr., Div. of San. & Eng., Alaska Dept. of Health, Box 1931, Juneau, Alaska (Jr. M. Oct. '50)

Johnson, Floyd V., Salesman, Mueller Co., 607 Cantrell Ave., Nashville 5, Tenn. (Oct. '41) *P*

Johnson, Laurence E., 734 Lama Dr., Lodi, Calif. (Jan. '45) *P*

Johnson, Winfred Ellis, Pres., White Rock Water Works Co., Ltd., Box 269, White Rock, B.C. (Apr. '49) *M*

Jones, James Ronald, 70 Linden St., Allston, Mass. (Jr. M. Oct. '50)

Kass, Edwin A., Gibbs & Hill, Inc., Pennsylvania Station, New York 1, N.Y. (Jan. '50) *P*

Kline, Harry F., Jr., 861 Crockett, Memphis, Tenn. (July '48)

Laffey, William T., 1324 Kynlyn Dr., Wilmington, Del. (Apr. '51) *P*

La Marre, Rene J., 10360 Crocuslawn, Detroit 4, Mich. (Jan. '35) *Director '47–'50.*

Larsen, Elwood M., Regional Engr., Sarasota County Health Dept., County Court House, Sarasota, Fla. (July '51)

Lauman, C. W., & Co., Inc., Herman E. Lauman, Pres., Box 341, Hicksville, N.Y. (Assoc. M. Oct. '44)

Lauman, Herman E., *see* Lauman, C. W., & Co., Inc.

Leonard, W. V., 1414 Alturas, Boise, Idaho (Apr. '39) *Fuller Award '47. P*

Ludwig, Harvey F., Office of Surgeon General, U.S. Public Health Service, 5614 Federal Security Bldg., N., Washington 25, D.C. (July '49) *Goodell Prize '43. P*

Luoma, Merlyn G., 202 Doublas Blvd., Ironwood, Mich. (Jan. '50) *P*

Maley, Alexander B., *see* Alexander Chemical Corp.

Mangun, Lloyd B., Huizache Courts, Saltillo, Coahuila, Mexico (Feb. '20)

Mara, Anthony, Supt. of Public Works, Township Parsippany Troy Hills, R.D. 1, Box 87, Parsipanny, N.J. (Apr. '39)

Morris, Robert Henry, 629 W. Macon St., Decatur, Ill. (July '48)

Mountain Water Co., Edward S. Souter, Gen. Mgr., 2908 Foothill Blvd., La Crescenta, Calif. (Corp. M. Oct. '47)

Parker, I. Curtiss, Cons. Engr., Parker, Hill & Ingman, 1728 E. Madison St., Seattle 22, Wash. (Jan. '41)

Randlett, Fred Morse, 950 S.W. 21st Ave., Portland 5, Ore. (June '20)

Reynolds, Albert H., Director, Product Development, Dearborn Chem. Co., Merchandise Mart, Chicago 54, Ill. (Dec. '29) *P*

Safford, Truman H., Engr., 317 S. Tryon St., Charlotte 2, N.C. (Oct. '49) *PR*

Simpson, Roy L., Chemist, Municipal Water Plant, 94 N. Gamble St., Shelby, Ohio (July '50)

Stock, Harry, Civ. Engr., Box 1764, Minot, N.D. (Jan. '39)

Summer, Billy Taylor, Resident Engr., Polk, Powell & Hendon, Box 678, Nashville 2, Tenn. (July '49) *P*

Swartz, Charles R., 213 Warren Way, East Point, Ga. (Jan. '49)

Tapia-Murillo, Gustavo, Casilla 760, Cochabamba, Bolivia (Oct. '48)

Thoman, John R., 741 Bulen Ave., Columbus 9, Ohio (Jan. '41)

Tillotson, Edwin S., Asst. Mgr., The Wichita Water Co., 301 N. Main St., Wichita, Kan. (Apr. '46) *M*

Toronto Dept. of Works, L. B. Allan, Comr. of Works, City Hall, Toronto 1, Ont. (Corp. M. Jan. '35)

Van Nocker, R. L., *see* Albert Lea (Minn.)

Vista Irrigation Dist., L. R. Burzell, Mgr., Box 696, Vista, Calif. (Corp. M. July '46) *MR*

Walborn, Herbert L., Mgr., Muhlenberg Township Authority, Kutztown Rd. & Monroe Ave., Hyde Park, Reading Pa. (July '51) *M*

Watson, Edmund J., Eng. Div., The Nestle Co., Colorado Springs, Colo. (Jan. '51)

Wildman, Quentin J., *see* Fort Dodge (Iowa) Water Dept.

Williams, W. T., Supt., Light & Water, 1501 Bighill Ave., Pawhuska, Okla. (Oct. '48) *MP*

Willis, Morris B., *see* Chillicothe (Mo.) Municipal Utilities

Condensation

Index of Abstracts

Page numbers refer to P&R section of Journal. Letters immediately preceding page numbers refer to month of issue, using following key: Ja—January; F—February; Mr—March; Ap—April; My—May; Je—June; Jl—July; Au—August; S—September; Oc—October; N—November. All subjects and page numbers in boldface type indicate first pages of topic sections or several abstracts on particular subject.

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Authors of Abstracted Articles

Page numbers refer to P&R section of Journal for 1951. Letters in italics immediately preceding page numbers refer to month of issue, in accordance with following key: Ja—January; F—February; Mr—March; Ap—April; My—May; Je—June; Jl—July; Au—August; S—September; Oc—October; N—November; D—December.

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The dedication to former superintendent H. F. Blomquist (right) of the addition to the Cedar Rapids, Iowa, filtration plant was marked by ceremonies attended by three Past-Presidents of A.W.W.A. Admiring the dedicatory plaque are Harry E. Jordan (President '35; second from left), and Jack J. Hinman (President '30; second from right); among the spectators was Edward Bartow (President '22). Blomquist served as superintendent of the Water Dept. from 1920 until his retirement two years ago. He planned the filter units, which double the plant's former 12-mgd. capacity, and construction was completed by his successor, Leo Louis.

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Section Meeting Reports

Alabama-Mississippi Section: The fourth annual meeting of the Alabama-Mississippi Section was held at the Buena Vista Hotel, Biloxi, Miss., on September 24–26, 1951. The total registration, including members, guests and ladies, was 181.

The morning of Monday, September 24, was devoted to registration, and the opening address was presented that afternoon with Chairman Tip H. Allen presiding. Mayor R. Hart Chinn of Biloxi appeared and gave the address of welcome.

E. E. Reid, executive director of the Alabama League of Municipalities, read a paper prepared by George J. Roark, city manager of Meridian, Miss., on the importance of a city's securing proper and adequate coordination of activities between municipal departments. Reid also discussed Alabama legislation sponsored by the league that has aided the water works authorities. One of these bills amended the "Revenue Act," which was discussed at length from the floor.

The train that brought Lewis M. Smith, vice-president and general manager of the Alabama Power Co., to the meeting was late, but he arrived in time to present his paper on "Public Relations," suggesting, however, that the railroad was not setting a good example for his subject. He advised that maintaining good public relations is a continuous operation and that water works men must remember that they are always telling their story to a parade that keeps right on moving. The most significant feature of the parade is that tomorrow there will be more people who haven't come by yet.

The technical session on Tuesday was presided over by Vice-Chairman E. M. Stickney. L. F. Scott, safety engineer for the U.S. Fidelity and Guaranty Co., discussed accident prevention as a principle, rather than dwelling upon details.

Martin Kunkel, U.S. Public Health Service sanitary engineer on loan to the Water Resources Division of the National Production Authority, ad-

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vised that the procedure for procuring critical materials had recently been changed. He explained the new regulations and answered many questions from the floor.

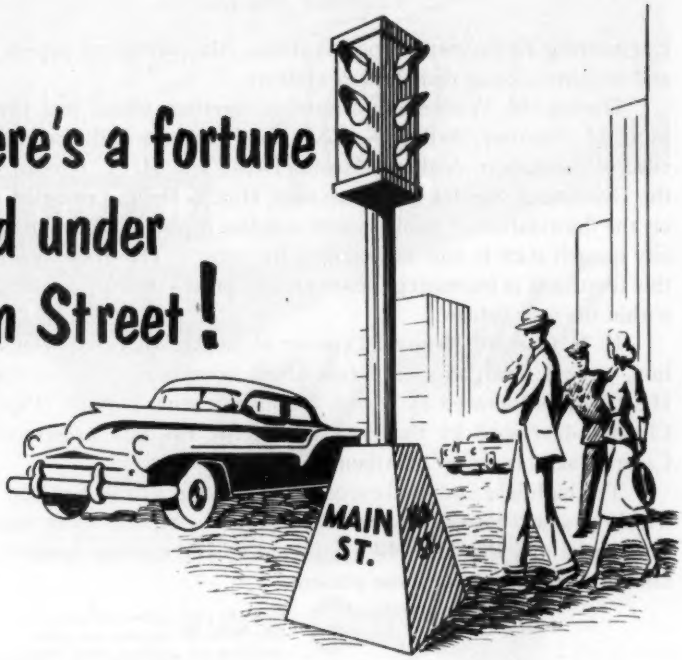
Henry J. Rechen, senior assistant sanitary engineer with the U.S. Public Health Service, discussed the very real need, since the advent of the atomic era, to include radiological health in the structure of general public health planning. The methods by which waters may become contaminated with radioactive materials and the present methods of control were discussed.

On Tuesday afternoon a boat trip to Ship Island was enjoyed by both the men and their wives who braved the elements. The "sunny south" was not prevailing at that time.

Chairman Allen presided over the Wednesday morning session, at which Gilbert H. Dunstan, professor at the University of Alabama, spoke on the first certification for water works operators in Alabama. A.W.W.A. President A. E. Berry then presented a most enlightening paper on current water works problems. W. H. H. Putman, general manager of the Birmingham, Ala., Water Works Board and Alex O. Taylor, director of the

(*Continued on page 64*)

There's a fortune buried under Main Street!



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Engineering Extension Service, Auburn, Ala., presented papers on records and maintenance of distribution systems.

During the Wednesday afternoon meeting, which was presided over by E. M. Stickney, Arthur N. Beck, chief engineer and director of the Bureau of Sanitation, Alabama Health Dept., and H. A. Kroeze, director of the Division of Sanitation, Mississippi Health Dept., presented discussions on the fluoridation of public water supplies in their respective states. One city in each state is now fluoridating its water. The demand for the use of this treatment is increasing, however, and other cities are expected to follow within the near future.

H. M. Gustard, Regional Director of the Alabama civil defense organization, gave a straightforward talk about complacency on civilian defense. His talk was followed by a very beautiful motion picture "Pipeline to the Clouds" developed by the General Electric Co. and presented by O. L. Cantrell, sales engineer of Atlanta, Ga.

The highlight and final event of the meeting was a "Seafood Jamboree" which was held instead of a formal banquet. Tip H. Allen was master of ceremonies and President Berry proved an entertaining speaker, endearing himself to the hearts of those present.

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The wives of the Alabama-Mississippi Section believe in attending the meetings, as is attested by the attendance of 58 of them. Special events planned for them included a sightseeing trip, luncheon, clubroom party, boat trip, and, of course, the cocktail party and "Seafood Jamboree" which the men also attended.

C. W. White
Secretary-Treasurer

Missouri Section: The fourth annual meeting of the Missouri Section was held at the Robidoux Hotel, St. Joseph, on September 30 to October 2, 1951, with 202 members and guests registered. One of the highlights of the meeting was a discussion on "Procurement of Materials" by A.W.W.A. Executive Assistant Secretary, Raymond J. Faust. The maintenance of accurate inventory records was emphasized and the existing confusion on self-assigned ratings and National Production Authority ratings was greatly clarified.

Stephen C. Casteel, assistant manager of the East St. Louis and Interurban Water Co., presented a timely discussion entitled "The Keystone

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is the Foreman." Frank C. Amsbary Jr., vice-president and secretary of the Northern Illinois Water Corp., Champaign, Ill., gave an enlightening discussion on "The Impact of Air Conditioning on Water Plant Operation."

"Protective Coatings for Metal Surfaces in Water and Sewage Plants" was discussed by H. J. Benjes of Black & Veatch, Kansas City, Ray O. Joslyn, manager of the Layne-Western Co., Kansas City, spoke on "Rehabilitation of Water Wells."

"Standardized Mechanical-Joint Cast-Iron Pipe" was discussed by Thomas F. Wolfe, managing director of the Cast Iron Pipe Research Assn., Chicago.

A paper on "A Practical and Possible Civil Defense Program for Water and Sewage Plants" was contributed by Ralph Hammond, state director of civil defense. The disaster theme was continued by two additional papers: "The Effect of Atomic Warfare on Water and Sewage Plants" presented by Conrad P. Straub, Oak Ridge National Lab., Oak Ridge, Tenn., and "Floods and a Disaster Plan," by Melvin P. Hatcher, director of the Kansas City Water Dept.

The motion picture "Pipeline to the Clouds" was presented by J. J. Miller of the General Electric Co. This is a very fine presentation and is a worthy successor of "Clean Waters," which was also produced by that company.

The technical sessions ended with a manufacturer's forum, an inspection of the St. Joseph water purification plant and a demonstration by the U.S. Public Health Service of an emergency water purification unit.

The Fuller Award nomination went to Vance C. Lischer, consulting engineer with Horner and Shifrin, St. Louis. Now in Pakistan on a Point Four mission (*see* Correspondence, p. 78), Lischer is well known among water works personnel for his work on hydraulics, particularly on water hammer. The nomination for the award was made at the annual banquet and was followed by a musical program and an address by W. Van Murchie entitled "It's All in the Point of View."

W. A. Kramer
Secretary-Treasurer

West Virginia Section: The 13th annual meeting of the West Virginia Section was held in Charleston on October 4–5, 1951, with headquarters at the Daniel Boone Hotel. The meeting immediately followed the 5th Conference of the West Virginia Sewage and Industrial Wastes Assn., with one technical session and the banquet being sponsored jointly by the two groups.

The registration of 156 was the second highest ever recorded at a Section Meeting in West Virginia. Attendance at technical sessions remained high throughout the meeting.

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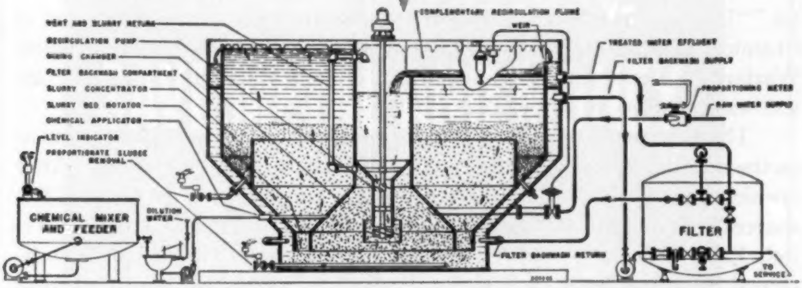
UNIFORM TREATMENT UNDER VARIABLE LOAD CONDITIONS



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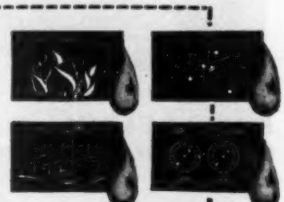

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Although not scheduled as part of the regular meeting, a special session was held the afternoon of October 3, 1951, for representatives of the larger public water systems in the state, and the theme of the discussions was "Selected Problems of Civil Defense of Water Works." Topics covered were: "Defense Against Sabotage," "Detection of Radiation in Water," "Use and Interpretation of Routine Control Tests for the Detection of Chemical Warfare Agents" and "Public Water Supply and Bacteriological Warfare." The special session was held in the Charleston Filtration Plant and was attended by 30 persons.

The first regular session was held jointly with the sewage association on the morning of October 4, with Chairman W. S. Staub presiding. After opening with a showing of the film "West Virginia and its Natural Resources," Frank M. Middleton, chemist at the U.S. Public Health Service's Environmental Health Center in Cincinnati, Ohio, discussed "Fundamental Studies of Taste and Odor in Water." The removal and subsequent extraction and identification of taste substances deposited in activated carbon filters constitute a new technique which holds future promise. W. M. Ingram, biologist, Ohio and Tennessee Drainage Basins, U.S. Public Health

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Service, Cincinnati, Ohio, evaluated the services of the biologist in water supply and pollution control in his paper, "Biological Investigations in Water Pollution Control." The morning session was concluded with an address by T. J. Gillooly, state assistant attorney general, on "Summary and Significance of Water Commission Court Cases."

The afternoon session opened with a presentation of the film "Underground Arteries" by the Johns-Manville Co. Douglas H. Spaton, Burrough Co., Charleston, next discussed "Billing Methods for the Modern Utility." The balance of the afternoon was devoted to a "Fluoridation Round-up" in which R. W. Ochershausen gave a thorough and up-to-date account of "Fluoridation Chemicals" and methods of feeding them and R. S. Jacobson, junior engineer with the State Dept. of Health, discussed "Laboratory Control of Fluoridation," pointing out control problems which have developed in West Virginia. Three fluoridation installations in the state were described and commented on by A. R. Todd, superintendent of the Wheeling Water Works; Frank J. De Franco, superintendent at Weirton; (W. Va.) and R. S. Jacobson substituting for R. B. Parsons of Ripley.

A business meeting of the section was held on the afternoon of October 4.

A very fine banquet was enjoyed by a record crowd of 226 on Thursday evening. N. H. Baker, acting director of the Bureau of Dental Health, State Dept. of Health, served as toastmaster. Brief remarks were made by A.W.W.A. Executive Assistant Secretary Faust. An ensemble of the Charleston High School band accompanied by 12 majorettes entertained with music and fresh dance routines.

The morning meeting on October 5, opened with a presentation of the film, "Tokyo, Japan, Water Works." Explanatory remarks about public water supply conditions in Japan were made by T. A. Stout of the engineering staff, West Virginia Water Service Co., Charleston. He had spent several years in Japan following World War II.

H. K. Gidley, director of the Div. of Sanitary Engineering, State Dept. of Health, Charleston, discussed "Observations on Operation of Upflow Clarifier for Turbidity Removal," comparing a plant using a conventional basin and a similar plant using a high rate upflow unit.

T. A. Stout's discussion, "Maps and Records of Distribution System Valves for Emergencies in War and Peace," was timely. Working examples of maps and records were displayed.

A.W.W.A. Assistant Secretary Faust gave a clear and concise picture of the materials situation and emphasized the importance of carefully following the CMP directives. He pointed out that shortages of certain controlled materials needed in water works operation will become increasingly acute in the future.

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Charles R. Fox, adjutant general and state director of civil defense, discussed "West Virginia's Civil Defense Plan," stressing the importance of public water supplies in civil defense. He also pointed out that strong leadership is essential for the establishment of a good civil defense program.

The West Virginia Water Service Co. and its president, T. J. Blair Jr., were unusually generous hosts and served the group a fine luncheon at the Daniel Boone Hotel. On the previous day, Mrs. T. J. Blair had entertained the ladies at a luncheon at the Edgewood Country Club.

The meeting closed with a visit to the Charleston filtration plant. Items of special interest were the 2,000-lb. per day master chlorinator, and a display of motorized equipment used to operate and maintain a water system extending approximately 30 miles along the Kanawha River.

H. K. Gidley
Secretary-Treasurer

Southwest Section: The Southwest Section held its 40th annual meeting in Fort Worth, Tex., Oct. 15–17, 1951, with Uel Stephens, superintendent of the Fort Worth plant, serving as host. The registration total was 702.

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Three full days were devoted to program papers and discussions. The sessions were well attended, and the program started with a fine address by A.W.W.A. President Albert E. Berry on "Today's Water Works Problems," given at a group luncheon session.

During the Monday afternoon session, a paper was presented on "The Inter-agency Approach to a Comprehensive Study of the Arkansas-White-Red River Basins," by L. W. Prentiss, division engineer, Southwestern Div., Corps of Engineers, U.S. Army, Dallas, Tex.

"Bacterial Warfare and its Effect on Water Supply" was discussed by Vincent B. Lamoureux, environmental sanitation consultant, Federal Civil Defense Administration, Washington, D.C. A paper on "Tastes and Odors in Southwestern Surface Waters" followed, presented by J. K. G. Silvey, professor of biology and chairman of the Science Dept., North Texas State College, Denton.

A panel discussion on civil defense was conducted by J. R. Pierce, vice president, General Waterworks Corp., Pine Bluff, Ark.; Conrad P. Straub, Health Physics Div., Oak Ridge National Labs., Oak Ridge, Tenn.; and Horace Sprague, coordinator for civil defense, American Red Cross, St. Louis.

Papers presented on the last two days of the meeting included: "Cooperation Between Utilities in Corrosion Control," by H. H. Anderson, vice president and general manager, Shell Pipe Line Corp., Houston, Tex., and "Regional Development of Water Supply in Texas Permain Basin," by S. W. Freese, Freese and Nichols, consulting engineers, Fort Worth, Tex. A panel discussion on materials procurement was conducted by M. B. Cunningham, superintendent and engineer, Oklahoma City Water Dept., Oklahoma City; Karl F. Hoefle, director, Water Dept., Dallas, Tex.; R. M. Dixon, managing director, Municipal Contractors Assn., Dallas, Tex.; and Harvey Howe, director, Water Resources Div. National Production Authority, Washington, D.C.

"College Water Plant Serves City and State," was the theme of a paper presented by N. C. Burbank Jr., assistant professor of civil engineering and Quintin B. Graves, professor of civil engineering, both of the Oklahoma Inst. of Technology, Oklahoma A.&M. College, Stillwater. A panel discussion on fluoridation was conducted by Clayton H. Billings, senior engineer with the Texas State Dept. of Health, Austin.

As usual, a most interesting breakfast session was conducted by Edward R. Stapley, dean of Oklahoma Inst. of Technology, with 160 present.

Larry Embree, Magnolia, Ark., received the Egmont S. Smith Scholarship Award for the second time. The Fuller Award went to L. C. Billings, chief chemist of the Dallas, Tex., Water Dept.

LESLIE A. JACKSON
Secretary-Treasurer


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(Continued from page 22)

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RICHARD D. HOAK

Senior Fellow
Mellon Inst.
Pittsburgh, Pa.; Nov. 9, 1951

To Scotsman Weir, we—fortified by consultation with the highest authorities of the liquor business—shouldn't have to point out that there ain't no 43 per cent. The 86 per cent is a unit —half alcohol and half water though it may be. Thus, only the 14 per cent is all *water. Twist their arm, though, and the authorities may admit that Scotch is actually, not 57 for the proof is really 86.8, but 56.6 per cent distilled water. But who wantsh to twish their armsh?*

Ash for Mishter Hoak, we're taking refuge in our condition for the moment and sticking by the calculation of \$1,000,000 per mil.gal. tax, which we confess to computing from the figure of \$1.00 per gal. reported by the internal revenue people.

The shtuff we drink!—ED.

Problems in Pakistan

To the Editor:

As you know I am in Karachi in connection with the Technical Cooperation Administration (Point Four program) of the State Department to render technical assistance to the Pakistan Government on water and sewerage problems for the city of Karachi. Carroll Hill of Harland Bartholomew's office is also here with me on housing and planning problems.

Our reception by Pakistani officials and engineers is most gratifying. These people like America and Americans. They welcome and need our technical assistance and I am sure they are not looking for hand-outs. They are resourceful and ambitious

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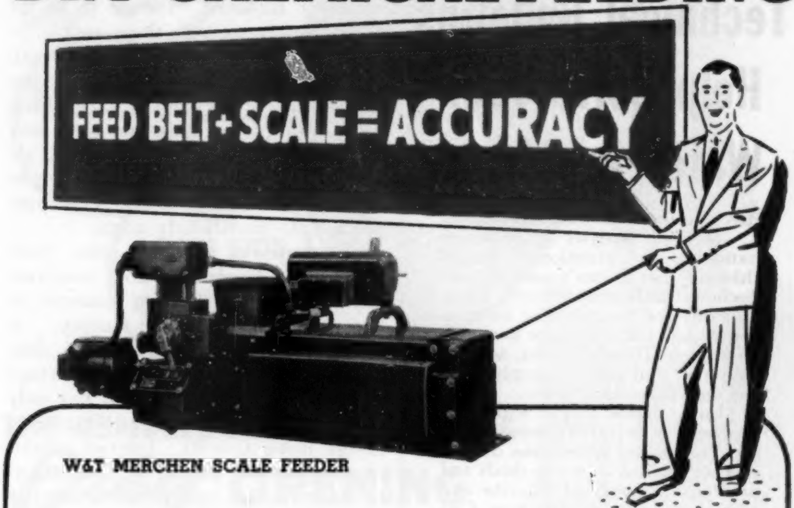
BASIC FORMULA FOR DRY CHEMICAL FEEDING



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M-16

(Continued from page 78)

people who are engaged in building a new nation under terrific handicaps and the unfortunate present threat of war over Kashmir. I want to do all in my power to help these people in the all too short time at our disposal.

Many critical materials problems perplex these people. Very little American goods finds its way into the water and sewerage systems, although American autos and goods are very evident elsewhere. The pipe problem is particularly acute.

Shipments of cast-iron pipe from France and England require over two years. Lead for jointing material is expensive and in short supply. A change to cement joints could save money here and solve one shortage problem. The pipe received has only superficial dipped coatings. Engineers design using $C = 90$. Interior deterioration occurs prematurely and external corrosion is a problem. Better coatings and linings are badly needed.

I believe prestressed concrete pipe should be used for large diameter pipe. Concrete materials are available and there are two cement plants near Karachi. Small-diameter pipe poses a more perplexing problem. Cement-asbestos pipe might be an answer.

Chlorine is very scarce and expensive here. I seem to recollect that there was a firm in U.S. which marketed an electrolytic chlorinator. Such a device might be useful here. On the other hand chlorine production is needed here because textile industries are being expanded. We shall suggest to the Pakistan government that they encourage the development of a chlorine plant here.

A new 60-mgd. purification plant is planned. They would like to consider American equipment. What is the attitude of American firms on this subject? Can they compete in today's foreign trade market? If any are interested, they are invited to mail literature to or get in touch with

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(*Continued from page 80*)

S. G. Murtaza, Chief Engineer, Karachi Joint Water Board, Karachi, Pakistan.

One of the disturbing problems here arises from the general practice in this part of the world of providing water service for only part of the day. Karachi with its 1,300,000 people is being supplied only 20 mgd., with service being rendered for only 3½ hours each day. Of course back-siphonage is unavoidable. Furthermore, each establishment has a ground and roof tank with a pump. Pollution under these conditions is inevitable. We are told all households boil their drinking water. Here at the hotel—the best in Karachi—however, the water is not boiled. Dysentery germs must be everywhere. Westerners cannot avoid it. Both Hill and I have been down with it.

The country here is desert, and water is the number one problem. The present supply is obtained partly from wells and partly from the Indus through inundation canals and a pontoon pumping station. They have a large reservoir about 40 miles from the city formed by a dike eleven miles around, all of which was constructed with hand labor with nothing more than donkey carts—and this in 1942.

. . . We visited yesterday the Lower Sind Barrage (dam on the Indus)—about 100 miles away—from which Karachi's entire water supply will ultimately come and on which much of the future of Pakistan depends. It is scheduled for completion in 1954–55. I saw there in the construction work large numbers of D–7 cats and scrapers. In one bit of levee (bund) construction there were nine such rigs working and, alongside them, the ancient method was in use—600 donkeys with about as many men. The donkeys had burlap sacks over their backs like saddle bags into which could be loaded about 3 cu.ft. of dirt. Each donkey carries about 150 cu.ft. per day and

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the owner is paid at the rate of 24 rupees (about $8) for 1,000 cu.ft. The D-7's handle 5 cu.yd. scrapers, so that in one round trip of about 10 minutes a scraper carries possibly 130 times as much as a donkey. They said the cost for the D-7's is half that for the ancient method.

I did not realize it before but they tell us heavy earth-moving equipment as used in the largest and most modern construction jobs is not available from any country but the United States. We saw several Bucyrus drag lines, Kohring cranes, Link-Belt cranes, Le Roi lighting plants on Chevrolet trucks, and many makes of American trucks. The superintending engineer, W. S. Hall, gave high praise to the Caterpillar engine. He said "nothing ever goes wrong with the engines." It all made me feel proud I was an American. The selling job for the American way that our products is doing contrasts sharply in my opinion with the shallow press and painted propaganda and with our often stupid foreign policy. I wish more American firms became interested in foreign markets. The world needs our machinery and technical help.

There is no outward evidence of stress here resulting from the assassination of Premier Liaquat Ali Kahn. We have heard no enmity expressed against the Afghans as a nation as a consequence. My regard for the Pakistani and their objectives increases every day. They are not too proud of some of the autocratic Muslim nations where there seems little hope for humanity much less for democracy. The Pakistani hope to set up a democratic form of government. The threats to world peace in the Muslim world—in Iran, in Egypt and over Kashmir—will hinder progress here immeasurably. There is greater need here for American products and know-how. From conversations with ordinary people here I gather that our best bid for the good will of foreign peoples is our manufactured goods. They're in demand and they are liked better than those of other countries. This opinion stems from top to bottom.

VANCE C. LISCHER
Karachi, Pakistan; Nov. 1, 1951

Real Sealer

To the Editor:

I was very pleased to receive notice that the seal submitted under my name had been selected second only to the "old seal."

The design was actually created and drawn by Mr. M. E. MacLean of this department. Thus the credit for the design should be given to Mr. MacLean and not to myself.

J. N. PRITCHARD

Principal Engr., Water Works Dept.
Ottawa, Ont.; Oct. 15, 1951

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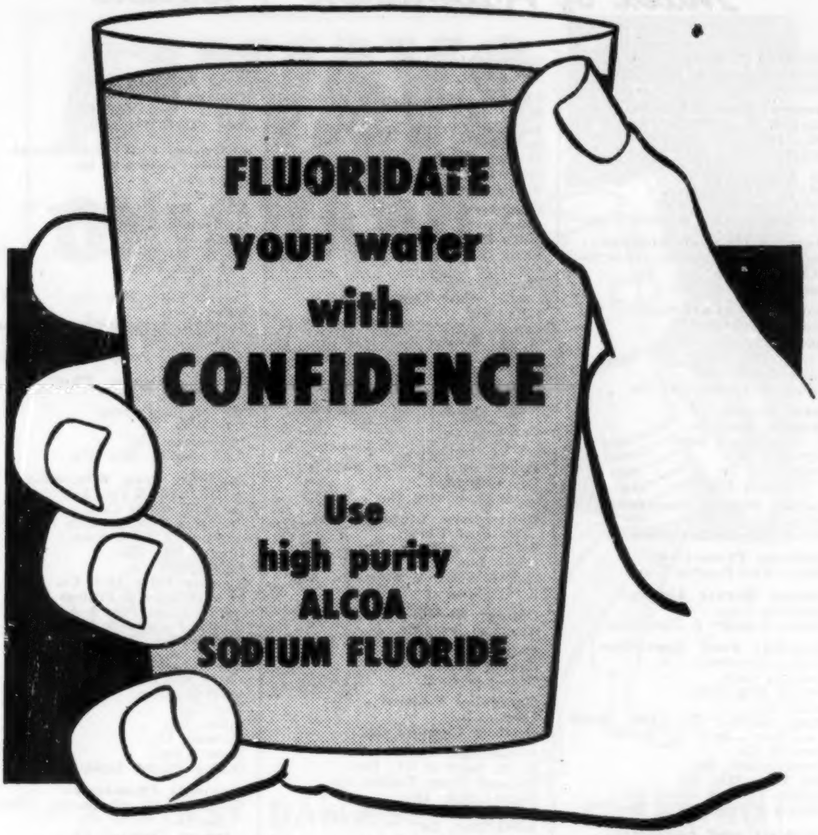
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